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INTERIM REPORT OF JOINT COMMITTEE ON MEASUREMENT OF PRODUCTIVITY

SHEET METAL AS A SUBSTITUTE FOR OTHER MATERIALS
by J. A. GRAINGER, A.M.I.Mech.E., A.M.I.P.E.

AN ENGINEER'S SURVEY OF THE IMPACT EXTRUSION PROCESS
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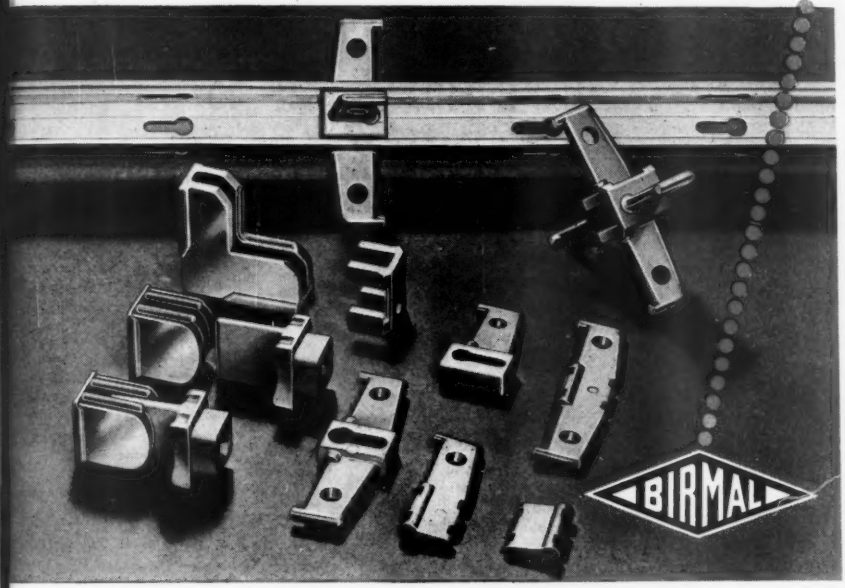

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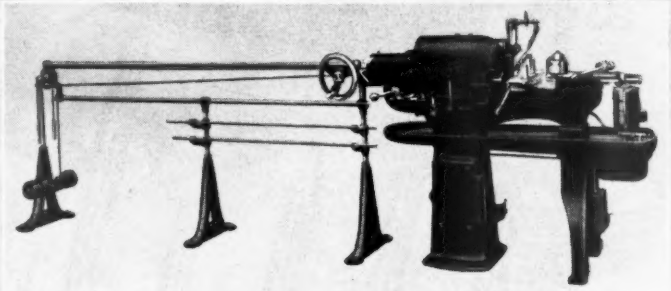

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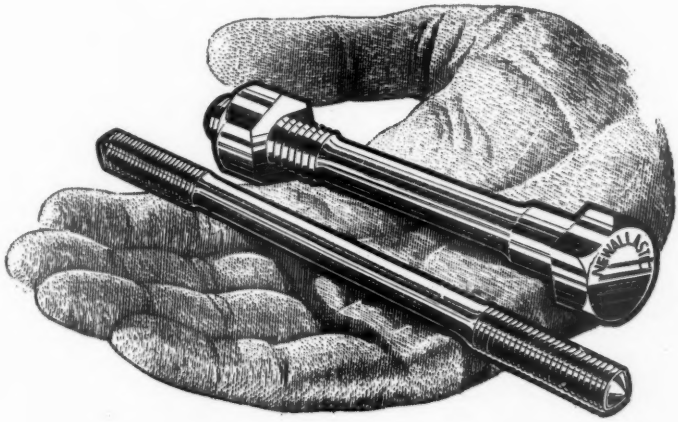

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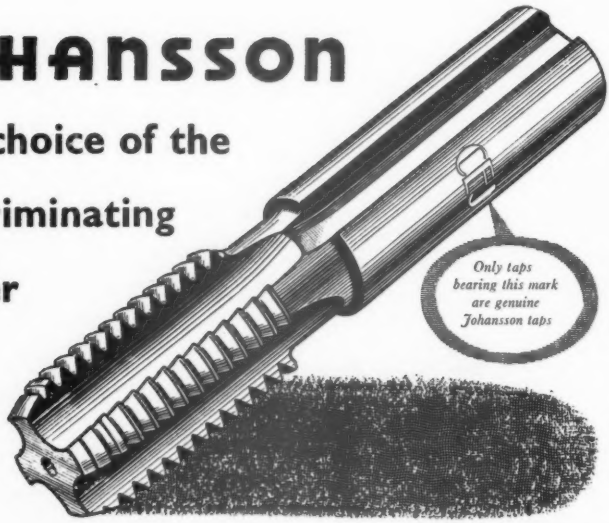

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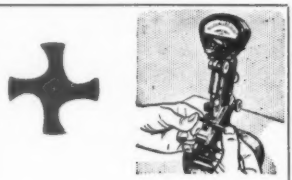

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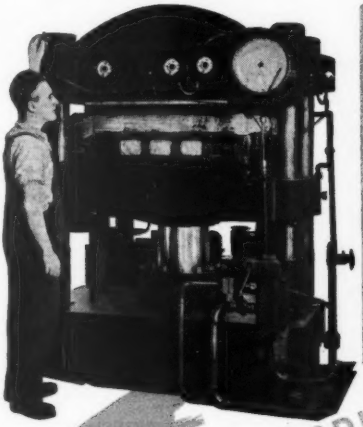

200-TON HYDRAULIC PRESSES

Photographs by courtesy of FERODO LTD.

* *A cold press of 200 tons capacity fitted with a 12" diameter ram—this unit is shown in action as an ejecting press stripping railway brake blocks from the hot dies after vulcanising.*

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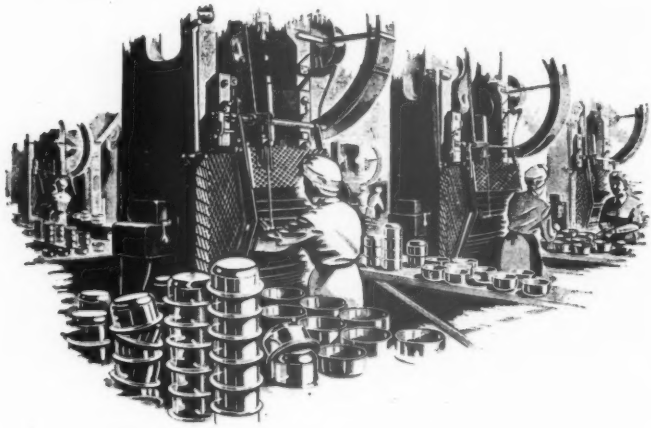

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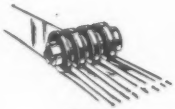

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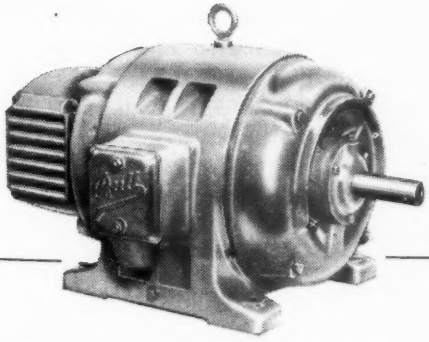

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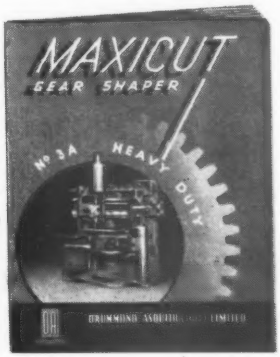

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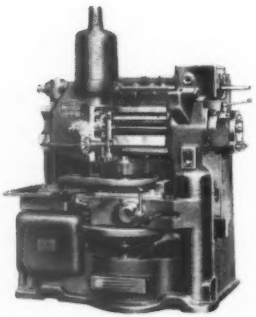

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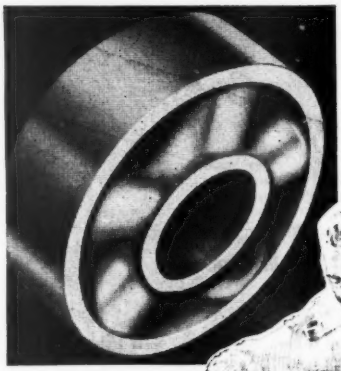

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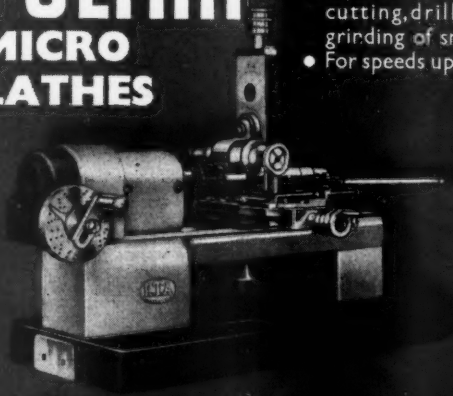

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Yorkshire	S. Metcalfe, 26, Highfield Avenue, Leeds, 12.

The President-Elect.
Major-General K. C. APPLEYARD, C.B.E.

The President-Elect.
Major-General K. C. APPLEYARD, C.B.E.
(Courtesy of Carlyle Studios, New York)

The President-Elect,

Major-General K. C. APPLEYARD, C.B.E.

Major-General K. C. Appleyard, C.B.E., President-Elect of the Institution, is an eminent industrialist. His extensive knowledge and wide experience, gleaned throughout a long and outstanding career, began when after completing his apprenticeship with C. A. Parsons and Company Ltd., he was appointed a Production Manager in one of the works of Sir W. G. Armstrong Whitworth & Company, Ltd., at a comparatively early age. He held this position until after the end of the First World War, when he was appointed General Manager of the Birtley Iron Company in Durham.

During the inter-war years from 1919 until 1939, General Appleyard quickly established a reputation as an industrialist of the first order. He became Chairman of Mining and Civil Engineering Contractors Ltd., Newcastle, Chairman of the first of the great Government Industrial Estates to be set up under the Special Areas Acts, and of Northern Industries Workrooms, Ltd., and a Local Director of the Special Areas Reconstruction Association, the latter being an organisation set up by the Treasury. At the same time he was Managing Director of the Birtley Company, Ltd., County Durham, mining plant engineers engaged on constructional work in Great Britain and all over the world, of the Koppers Coke Oven Company Ltd., Sheffield, and also of the Ross Engineering Company of Prague, and was President of the Société Birtley S.A., Brussels.

In addition to the scientific institutions indicated above, he is a member of the North East Coast Institution of Engineers and Shipbuilders, and the Iron and Steel Institute, and is a Past President of the Junior Institution of Engineers. In 1946 he was awarded a Telford Premium by the Institution of Civil Engineers. General Appleyard is also a recognised authority on all aspects of labour relations, having been a Member of General Council and of the Management Board of the Engineering and Allied Employers' National Federation and Chairman of the North East Coast Engineering Employers' Association for ten years until 1939.

In 1934 he was appointed Chairman of the Central Conference at York and held this office until he was mobilised at the outbreak of war. The tributes paid to him by the Engineering Trade Unions on relinquishing this important and difficult office themselves

witnessed to the success with which his work in this field had been carried out.

Not only is General Appleyard known for his achievements in the engineering world both in this country and abroad, but also for his distinguished military career in two World Wars. He is keenly interested in the Territorial Army and after the end of the 1914-18 War he rejoined it ; in 1937, on completion of his period of Command, he was promoted and awarded the Order of the British Empire. On Mobilisation in 1939 he was appointed Deputy Chief Engineer, Northern Command, and then Chief Engineer of the Royal Air Force Component of the Field Force in the British Expeditionary Force which was drafted to France in November, 1939. For his services to his country His Majesty the King conferred on him the honour of Commander in the Military Branch of the Order of the British Empire, and he was subsequently promoted to the rank of Major-General. He is at present Honorary Colonel of the 50th Division Royal Engineers and a Military Member of the Territorial Army and Air Force Association of the County of Durham.

In June, 1940, he was loaned to the Government by the Army, in order that he could be appointed Director of Labour Supply and Adviser to the Ministry of Labour and National Service, who had the enormous task of marshalling the entire civilian population and galvanising it into full activity wherever our war potential was weakest.

Thereafter followed a succession of appointments calling for the highest skill and administrative ability as Director of the International Labour Branch ; Director of Emergency Works in the Ministry of Works, in which appointment he was responsible for setting up the national organisation which carried out first aid repairs of all buildings damaged by enemy attack ; Director of Opencast Coal Production, and finally, Advisor to the Minister of Works on Regional Organisation, in which office he planned and supervised the carrying out of the decentralisation of the Ministry to enable it to deal with its heavy post war responsibilities with greater efficiency.

The President-Elect, as a member of the Durham County Council and Chairman of its Works Committee, had considerable experience of Local Government, and is a Deputy Lieutenant and Justice of the Peace for the County of Durham, Vice-President of Durham Municipal and County Federation, and a Member of Council of the North East Coast Development Board. Since 1947 he has been

a Director of many engineering companies both in Great Britain and in other countries, including Overseas Marketing Services, Ltd., R. H. Windsor, Ltd., Russell Newbery & Co., Ltd., and Blackwood Hodge Ltd.'s companies in India, Pakistan, Ceylon, and America. He is a well known consultant and advises a number of important companies, each in different industries, on their engineering industrial, and commercial problems.

General Appleyard's acknowledged talents and ability in industrial matters will be of inestimable value to the Institution and its members can regard themselves as extremely fortunate that a man of such exceptional prominence has accepted its invitation to take office as President-Elect.

INSTITUTION NOTES

December, 1949

MEETING OF COUNCIL

The next Meeting of Council will be held on Thursday, January 26th, 1950, at 11 a.m., at 36, Portman Square, London, W.1, followed by the Annual General Meeting.

A.A.C.P. TEAM REPORT ON STEEL FOUNDRIES

Members will have seen the published report of the Steel Foundries Team which visited the U.S.A. under the auspices of the Anglo-American Council on Productivity, and they will be interested to know that apart from publishing a condensed version of this Report, the British Steel Founders' Association are also organising a Technical Convention and other meetings in steel foundry centres, so that the maximum benefit can be derived from this Report of the team's findings.

ROYAL COMMISSION ON AWARDS TO INVENTORS

We are advised by the Royal Commission on Awards to Inventors that any claims for awards to inventors under Heads 1, 3 and 4 of the Royal Commission's terms of reference must be submitted to the Government Department concerned on or before 31st December, 1949. Claims for alleged use by the Navy should be sent to the Director of Navy Contracts, Patents Division, Foxhill, Bath, and those relating to the Army or Royal Air Force to the Ministry of Supply, Patents Division, Melbourne House, Aldwych, W.C.2. Any further information can be obtained from The Royal Commission on Awards to Inventors, North Wing, Somerset House, Strand, W.C.2.

COVENTRY SECTION CONFERENCE

With reference to the One Day Conference on "Mechanical Handling" to be held by the Coventry Section, as announced in the October issue of the Journal, it should be noted that the date has now been changed to May 20th, 1950.

TECHNICAL APPOINTMENT

The Redditch Technical School requires a full time instructor on Engineering Subjects ; ability to teach Workshop Technology, Jig and Tool Drawing, and Design to National Certificate Standard would be an advantage. The salary will be in accordance with the Burnham Scale.

Forms of application may be obtained by sending a stamped addressed envelope to the Director of Education, Castle Street, (S/J/11), Worcester, and should be returned to the Principal of the School as soon as possible.

SECTION AFFAIRS-CORRESPONDENCE Members are reminded that local Sections of the Institution are self-governing, and that each Section is represented on Council, which is the governing body, by the Section President.

In certain instances the Head Office has received letters from members concerning the conduct of local affairs. Such matters should of course be brought in the first instance to the notice of the Section President, as in a democratic organisation such as this Institution, it is important that members should adhere to the correct constitutional procedure.

MECHANICAL HANDLING

Members will be interested to know that at the Meeting of Council held on 20th October, 1949, it was decided that the Institution should take an active interest in the important subject of Mechanical Handling, and should through its Research Committee undertake operational research in this field.

The Research Committee are of the opinion that the task of the Production Engineer consists not only in the operation of machines but in the whole organisation of production, which includes means of moving material and components both inside and outside the factory.

Members will also be aware that the Institution's particular interest in this sphere has been officially recognised by the Anglo-American Council on Productivity by their invitation to the I.P.E. to send two representatives to America with the Specialist Team on Mechanical Handling, one of our representatives being asked to act as Secretary of the Team. The report which this team will issue on their return, and to which the I.P.E. representatives will make a major contribution, will have wide publicity and will be a document of the greatest national importance. It is therefore essential that the active interest of all members should be focussed on this aspect of our activities, in order that the fullest advantage may be taken of the experience gained by our two representatives when they return from the United States.

In addition, the next Exhibition of Mechanical Handling to be held at Olympia in 1950 will present a great opportunity for the Institution to show evidence of its interest in this most important subject. Incidentally, the Vice-Chairman of Council, Mr. Walter C. Puckey, has been invited to read a paper at this Exhibition, which he is calling "Mechanical Handling—A Production Engineer's Job."

Members will be aware that on May 20th, 1950, the Coventry Section have arranged to hold a One Day Conference on Material Handling, in collaboration with the Humber Company, Ltd. By this enterprising venture the Coventry Section have given a lead to the Institution, and it is hoped that many other Sections will follow suit, and arrange meetings and conferences on this subject. By this means, the Institution will be able to make a real contribution to national productivity.

The Research Committee will shortly appoint a Sub-Committee to investigate various aspects of mechanical handling with a view to initiating research, and will work in close collaboration with the University of Birmingham where Professor T. U. Matthew, Lucas Professor of Engineering Production, has generously offered to integrate the research work of his Department with any research work which the Institution may undertake in this field.

Invitation to Members.

The Research Committee feel that many members are already interested in this subject, and the Chairman invites all those who are willing to help the Committee to send in their names to Headquarters immediately.

NEWS OF MEMBERS

Mr. C. M. Anderson, A.M.I.P.E., has been appointed Production Manager to Robert Kellie & Son Ltd., Dundee.

Mr. E. Bamford, Stud.I.P.E., has been successful in the recent essay competition sponsored by the Institution of Works Managers on "The Selection and Training of Foremen," and has been awarded a bursarship tenable at the Y.M.C.A. College for Adults, Broadstairs. Mr. Bamford is now an apprentice at Rolls-Royce Ltd., Crewe.

Mr. S. Coates, A.M.I.P.E., A.R.Ae.S., Hon. Secretary of the Southern Section, has been appointed a full-time Lecturer in Engineering Subjects at Southampton Technical School.

Mr. H. Grisbrook, M.I.P.E., has recently been appointed Lecturer in Tool Engineering and Metrology in the Department of Engineering Production at the University of Birmingham, and will take up his duties early in the New Year.

Miss D. J. Lavender, Grad.I.P.E., has won the distinction of being Chief Student of the Wolverhampton and Staffordshire Technical College, as a result of five years' work in the Department of Engineering Production.

Mr. L. E. Luck, A.M.I.P.E., has been appointed Lecturer at Cardiff Technical College.

Mr. R. W. Marston, A.M.I.P.E., is now Assistant Works Manager at Fairbairn Lawson Combe Barbour, Ltd., Leeds.

Mr. R. J. Read, Grad.I.P.E., is now Technical Sales Representative in Birmingham for Protolite Ltd.

Mr. W. A. Theobalds, A.M.I.P.E., M.I.E.I., has been appointed Chief Inspector of Blackstone, Lister, Ltd., Stamford, Lincs.

The Late DR. GEORG SCHLESINGER, Hon.M.I.P.E.

The death of Dr. Georg Schlesinger, Hon.M.I.P.E., at the age of 75 is an inestimable loss not only to engineering in general, but in particular to the Institution of Production Engineers, with which he was closely connected as Director of the Research Department of the Institution from 1939 to 1944.

Dr. Schlesinger, who was an expert of world renown in production research, was perhaps best known for his work in connection with machine tool tests and alignments, although there was no aspect of modern production with which he was not familiar. He was the author of many works on machine tool design and standardisation, shop management, administration, and various aspects of industrial welfare, some of which were translated into many languages and accepted as standard works of reference throughout the world.

Born in Berlin, Dr. Schlesinger was educated at the Falk Real Gymnasium, Berlin, and received his Dip. Ing. degree at the Technical University of Charlottenburg. After spending some time in industry, in 1903 he prepared a Thesis on "Fits and Tolerances" and received his Dr. Ing. degree. In 1904, when he was Chief Designer and Principal of the apprentice school of Ludwig Loewe Gesfurel & Co., Berlin, he was appointed the first Professor of Production Engineering and Scientific Management at the Technical University of Charlottenburg.

During the First World War, Dr. Schlesinger was made responsible, under the German War Ministry, for the equipment of artificial limbs and the rehabilitation of disabled servicemen. Towards the end of the war, he was largely responsible for the foundation of the German Standards Association, and he spent many years carrying out work of the greatest value in machine tool research.

After the imposition of the Nazi regime in 1934, Dr. Schlesinger left Germany and accepted an appointment as Associate Professor at Brussels University, and in 1938, the Institution of Production

Engineers, recognising his outstanding ability, arranged for him to come to England where he took charge of the Institution's Research Department at Loughborough College. Here he remained until his retirement in 1944, after which his services were retained as a Consultant. Under his guidance and inspiration the Department achieved an international reputation in its own particular sphere as the first research organisation of its kind in this country, and paved the way for the formation of the Production Engineering Research Association of Great Britain.

In recognition of his great work, Dr. Schlesinger was elected an Honorary Member in 1942. He was also a member of the Institution of Mechanical Engineers, the American Society of Mechanical Engineers, and the Société Royale des Ingènieurs Belge Bruxelles.

BOOKS RECEIVED

" Questions and Answers." Published by Machinery Market, 146A Queen Victoria Street, London, E.C.4.

" Freedom and Co-ordination "—Lectures in Business Organisation, by Mary Parker Follett, edited by Lt.-Col. L. Urwick, O.B.E., M.C., M.A., M.I.P.E., F.I.I.A. Published by Management Publications Trust Ltd., price 5/- net.

" Training for a Career," published by Tube Investments Ltd. This well produced booklet gives comprehensive information concerning careers with the Tube Investments Group of Companies. It shows how the Group Training policy is implemented with regard to the activities of the various companies of the Group, and by photographs and charts illustrates the care taken to ensure a balanced training for various grades of personnel. All concerned with education and training will find much interest in the wealth of information given. T.B.W., M.I.P.E.

" Taper Calculation and Inspection." Published by Machinery Publishing Co. (Yellow Back Series), price 3/6d.

" Goods Vehicle Operation," by C. S. Dunbar, M.Inst.T. Published by Iliffe & Sons, Ltd., London, price 10/6d. net.

" The Factory," by Dr. (Ing.) G. Schlesinger. Published by Sir Isaac Pitman & Sons, Ltd., London. Price 70/- net.

This book contains a wealth of information which should prove of great value to all interested in factory administration and production problems, and its contents were to be expected from the pen of so highly experienced an authority on such matters.

The book deals with fundamental problems of materials, labour, overheads, plant, management, administration and economic control that may beset management and production engineer alike.

A selection of various industries have been investigated and examples are given of how these problems were solved. This book

should also provide a very valuable contribution to the training of students in production and management administration. The author has certainly presented a work which should prove of great value to industry in general. A.R., A.M.I.P.E.

IMPORTANT In order that the Journal may be despatched on time, it is essential that copy should reach the Head Office of the Institution not later than 40 days prior to the date of issue, which is the first of each month.

ISSUE OF JOURNAL TO NEW MEMBERS Owing to the fact that output has to be adjusted to meet requirements, and in order to avoid carrying heavy stocks, it has been decided that the Journal will only be issued to new Members from the date they join the Institution.

SECTION MEETINGS

The following meetings have been arranged to take place in December 1949, and January 1950. Where full details are not given, these have not been received at the time of going to press.

December

1st WESTERN SECTION. The Annual Dinner and Dance to be held at the Berkeley Cafe, Bristol, at 7-00 p.m. (for 7-30 p.m.) will be attended by the President of the Institution and the Lord Mayor of Bristol.

2nd WEST WALES SUB-SECTION. A lecture on "Quality Control" will be given by Dr. B. P. Dudding, M.B.E., Ph.D., in the Civic Buildings, Swansea, at 7-30 p.m.

5th HALIFAX SECTION. A lecture on "The Production of Form Grinding Wheels by Crushing and Diamond Dressing" will be given by Mr. S. J. Harley, B.Sc., M.I.Mech.E., M.I.P.E., at the White Swan Hotel, Halifax, at 7-15 p.m.

5th YORKSHIRE SECTION. A lecture on "The Latest Development of Grinding Machines," will be given by Mr. G. H. Bottomley, at the Hotel Metropole, King Street, Leeds, 1, at 7-00 p.m. This lecture will be followed by a Works Visit on 7th December, to John Lund Ltd., Cross Hills, Keighley

6th BIRMINGHAM. A Buffet Dance and a Christmas Party and Dance have been arranged by the Senior and Graduate Sections to take place at the Grand Hotel, Birmingham.

December—*cont.*

7th NOTTINGHAM SECTION. A lecture on " Development in Plastics " will be given by Dr. Pepper, at the Victoria Station Hotel, Milton Street, Nottingham, at 7-00 p.m.

7th WOLVERHAMPTON SECTION. A lecture on " Foundry Technique in Relation to Engineering Production " will be given by Mr. G. R. Shotton, at the Dudley and Staffordshire Technical College, Dudley, at 7-00 p.m.

7th PRESTON SECTION. A lecture on " Costing as an Aid to Management " will be given by Mr. H. H. Norcross A.I.P.E., F.C.W.A., F.I.I.A., at Clayton, Goodfellow & Co., Ltd., Atlas Iron Works, Park Road, Blackburn, at 7-15 p.m.

7th WESTERN SECTION. A lecture on " The Measurement of Productive Efficiency " will be given by Mr. W. C. Puckey M.I.P.E., F.I.I.A., at the Grand Hotel, Bristol, at 7.15 p.m.

8th DERBY SUB-SECTION. A lecture on " Industrial Design " will be given by Mr. W. N. Rodgers, at Becket Street Sales Room at 7-00 p.m. This will be a joint meeting with the Institute of Industrial Administration.

8th LONDON SECTION. A lecture on " Budgetary Control and Standard Costs from the Production Engineer's Standpoint " will be given by Mr. L. W. Robson, F.C.A., F.C.W.A. at the Royal Empire Society, Northumberland Avenue, London, W.C.2, at 7-00 p.m.

9th COVENTRY SECTION. A lecture on " Defects and Developments in Deep Drawing and Pressing " will be given by Dr. J. D. Jevons, B.Sc., F.R.I.C., F.I.M., at the Greyfriars Rooms, The Geisha Cafe, Hertford Street, Coventry, at 7-00 p.m.

9th LONDON GRADUATE SECTION. A report on the Swiss Industrial Tour, June 1949, will be given, followed by a discussion on arrangements for future tours, at the Institution of Production Engineers, 36 Portman Square, London, W.1, at 7-15 p.m.

10th YORKSHIRE GRADUATE SECTION. A lecture on " Design of Gearing " will be given by Dr. W. A. Tuplin, D.Sc., M.I.Mech.E., at the Great Northern Station Hotel, Leeds, 1, at 2-30 p.m.

12th SHEFFIELD SECTION. A lecture on " Coal Production Methods " will be given by Mr. R. G. Baker, at the Royal Victoria Station Hotel, Sheffield, at 6.30 p.m.

December—*cont.*

13th BIRMINGHAM GRADUATE SECTION. A lecture on "Motion Study" will be given by Miss Anne G. Shaw, M.A., M.I.P.E., at the James Watt Memorial Institute, Great Charles Street, Birmingham, at 7-00 p.m.

13th WOLVERHAMPTON GRADUATE SECTION. A lecture on "An Engineer's Survey of the Impact Extrusion Process" will be given by Mr. R. Hanes, M.A., G.I.Mech.E., at the County Technical College, Wednesbury, at 7-15 p.m.

13th DUNDEE SECTION. A "Short Papers" evening will be held at Mathers Hotel, Whitehall Crescent, Dundee, at 7-15 p.m.

14th LIVERPOOL SECTION. A Discussion on "The Effective Use of Materials" will be held at the Exchange Hotel, Tithebarn Street, Liverpool, at 7-15 p.m.

14th LUTON GRADUATE SECTION. A lecture on "Plastics in Engineering" will be given by Mr. Y. W. Rayden, accompanied by a sound colour film on "Fabrication of Perspex," in the Small Assembly Room, Town Hall, Luton, at 7-30 p.m.

14th NORTH EASTERN SECTION. A lecture on "Cast Iron as an Engineering Material" will be given by Dr. H. T. Angus, in the Neville Hall Mining Institution, Westgate Road, Newcastle-on-Tyne, at 7-00 p.m.

15th GLASGOW SECTION. A lecture on "Modern Surface Coatings" will be given by Mr. C. A. J. Taylor, M.Sc., A.R.I.C., at the Institution of Engineers and Shipbuilders, 39 Elmbank Crescent, Glasgow, C.2, at 7-30 p.m.

15th LEICESTER SECTION. A lecture on "Applying Air to Work Holding Fixtures," illustrated by lantern slides and equipment under operation, will be given by Mr. Christopher Willcox, in Room 104, the Leicester College of Technology, The Newarke, Leicester, at 7-00 p.m.

15th MANCHESTER GRADUATE SECTION. A lecture on "Design for Welding" will be given by Mr. F. Koenigsberger, A.M.I.P.E., in the Reynolds Hall, College of Technology, Manchester, at 7-15 p.m.

15th LONDON GRADUATE SECTION. A visit to the British Oxygen Co., Ltd., Angel Road, Upper Edmonton, London, N.18, commencing at 2-30 p.m. has been arranged.

December—*cont.*

16th COVENTRY GRADUATE SECTION. A lecture on "Surface Finish and Its Measurement" will be given in Room A.5, Coventry Technical College, The Butts, Coventry, at 7-15 p.m.

16th EASTERN COUNTIES SECTION. A lecture on "Metallurgy and Its Importance to Production Engineering" will be given by Dr. A. R. E. Singer, at the Britannia Works, Colchester, at 7.30 p.m.

16th NORTH EASTERN GRADUATE SECTION. A lecture on "Calculations Involving Tolerances" will be given by Mr. W. York, Grad.I.P.E., in the Neville Hall Mining Institution, Westgate Road, Newcastle-upon-Tyne, 1, at 7-00 p.m.

19th DERBY SUB-SECTION. A lecture on "Induction Heating" will be given by Mr. W. S. G. Cosgrave, B.Sc., A.I.M., at the School of Art, Green Lane, Derby, at 7-00 p.m.

19th MANCHESTER SECTION. A lecture on "Control of Overhead Cost" will be given by Mr. T. G. Rose, M.I.Mech.E., M.I.P.E., F.I.I.A., at the College of Technology, Sackville Street, Manchester, at 7.15 p.m.

20th LUTON, BEDFORD AND DISTRICT SECTION. A lecture on "Sheet Metal as a Substitute for Other Material" will be given by Mr. J. A. Grainger, A.M.I.P.E., in the Small Assembly Room, Town Hall, Luton, at 7-00 p.m.

21st EDINBURGH SECTION. A lecture on "Scotland's New Industries" will be given by Mr. C. A. Oakley, B.Sc., Ed.B., at the North British Station Hotel, Edinburgh, at 7-30 p.m.

January

2nd YORKSHIRE SECTION. A lecture on "Modern Measuring and Inspection Equipment and Its Application" will be given by Mr. E. Clarke, at the Hotel Metropole, King Street, Leeds, 1, at 7-00 p.m.

4th NOTTINGHAM SECTION. A lecture on "Noise and Vibration in Machinery" to be illustrated by slides, will be given by Dr. W. A. Tuplin, D.Sc., M.I.Mech.E., at the Victoria Station Hotel, Milton Street, Nottingham, at 7-00 p.m.

January—*cont.*

4th WOLVERHAMPTON SECTION. A lecture on " Mechanical Mishaps and Their Relation to Design and Workmanship " will be given by Mr. G. E. Windeler, M.C.E., M.I.Mech.E., M.I.Mar.E., at the West Midland Gas Board Demonstration Room, Clarence Street, Wolverhampton, at 7-00 p.m.

5th GLASGOW SECTION. An Informal Discussion on " Metal Cutting " led by Mr. G. V. Stabler, will be held at the Institution of Engineers and Shipbuilders, 39 Elmbank Crescent, Glasgow, C.2, at 8-00 p.m.

6th WEST WALES SUB-SECTION. A lecture on " The Production Engineer—His Education and Training " will be given by Mr. T. B. Worth, M.I.Mech.E., A.M.I.E.E., M.I.P.E., in the Civic Buildings, Swansea, at 7-30 p.m.

7th YORKSHIRE GRADUATE SECTION. A visit has been arranged to the Yorkshire Copper Works Ltd., Stourton, Leeds, 10, commencing at 2-15 p.m.

9th SHEFFIELD SECTION. A lecture on " Education of a Production Engineer " will be given by Dr. H. Schofield, C.B.E., M.I.P.E., at the Royal Victoria Station Hotel, Sheffield, at 6-30 p.m.

10th BIRMINGHAM GRADUATE SECTION. A lecture on "Production Management's Responsibility for Productivity" will be given by Mr. B. H. Dyson, M.I.P.E., F.I.I.A., at the James Watt Memorial Institute, Great Charles Street, Birmingham, at 7-00 p.m.

10th WOLVERHAMPTON GRADUATE SECTION. A lecture on " Planning " will be given at the West Midland Gas Board Demonstration Room, Darlington Street, Wolverhampton, at 7-15 p.m.

11th PRESTON SECTION. A lecture on " Payment by Results " will be given by Mr. A. J. Charnock, M.I.P.E., at the Harris Institute, Corporation Street, Preston, at 7-15 p.m.

11th WESTERN SECTION. A lecture on " Incentives for Production " will be given by Mr. C. L. Taylor, A.M.I.P.E., at the College, Swindon, at 7-30 p.m.

12th HALIFAX GRADUATE SECTION. A lecture on " Metal Spraying " will be given by Mr. W. Wall, at the Halifax Municipal Technical College, Halifax, at 7-00 p.m.

January—*cont.*

13th COVENTRY SECTION. A lecture on " Factory Administration from the Accountants' Viewpoint " will be given by Mr. E. A. Hyde, A.I.P.E., at the Greyfriars Rooms, The Geisha Cafe, Hertford Street, Coventry, at 7-00 p.m.

13th EASTERN COUNTIES SECTION. A lecture on " Industrial Applications of the Lost Wax Process " will be given by Mr. A. Short, A.M.I.P.E., in the Lecture Hall, Electric House, Ipswich, at 7.30 p.m.

16th DERBY SUB-SECTION. A lecture on " Modern Milling Practice " will be given by Mr. W. S. B. Kidd, at the School of Art, Green Lane, Derby, at 7-00 p.m.

17th DUNDEE SECTION. A lecture on " British Management at the Cross Roads " will be given by Mr. Lewis C. Ord, at Mathers Hotel, Whitehall Crescent, Dundee, at 7-15 p.m.

17th MANCHESTER GRADUATE SECTION. A lecture on " Recent Improvements in Production Methods " will be given by the Section Chairman, Mr. R. Cleary, G.I.Mech.E., Grad.I.P.E., in the Reynolds Hall, College of Technology, Manchester, at 7-15 p.m.

18th BIRMINGHAM SECTION. A lecture on " The Nature and Economics of the Machine Tool Industry " will be given by Messrs. W. V. Hodgson, M.I.P.E., and E. A. Hyde, A.I.P.E., at the James Watt Memorial Institute, Great Charles Street, Birmingham, 3, at 7-00 p.m.

18th EDINBURGH SECTION. A lecture on " Education for Management " will be given by Lt.-Col. L. Urwick, O.B.E., M.C., M.A., C.I.Mech.E., M.I.P.E., F.I.I.A., at the North British Station Hotel, Edinburgh, at 7-30 p.m. This is a joint meeting with the East of Scotland Branch of the Institute of Personnel Management.

18th LIVERPOOL SECTION. A lecture on " Valid Incentives " will be given by Mr. E. C. Gordon England, F.R.Ae.S., M.I.P.E., F.I.I.A., at Radiant House, Bold Street, Liverpool, at 7-15 p.m.

18th LUTON GRADUATE SECTION. A lecture on " Modern Adhesives " will be given by Mr. T. C. Ford, Stud.I.P.E., in the Small Assembly Room, Town Hall, Luton, at 7-30 p.m.

18th MANCHESTER SECTION. A lecture on " Effective Use of Materials " will be given by Mr. R. F. Archer, at the Mechanics' Institute, Crewe, at 7-15 p.m.

January—*cont.*

18th NORTHERN IRELAND SECTION. A lecture on "Material Handling" will be given by Mr. Hartford M. King, at the Municipal College of Technology, Belfast, at 7-00 p.m.

18th WESTERN SECTION. A lecture on "Production and Inspection on Gears" will be given by Mr. J. Milwain, M.I.P.E., M.I.E.I., at The Grand Hotel, Bristol, at 7-15 p.m.

19th GLASGOW SECTION. A lecture on "Apprentice Training" will be given by Mr. C. A. Packer, A.M.I.Mech.E., at the Institution of Engineers and Shipbuilders, 38 Elmbank Crescent, Glasgow, C.2, at 7-30 p.m.

19th LONDON SECTION. A lecture on "The Relation Between Technical Education, Training and Production" will be given by Messrs. T. W. Price, M.I.P.E., A.I.I.A., and T. B. Worth, M.I.Mech.E., A.M.I.E.E., M.I.P.E., at the Royal Empire Society, Northumberland Avenue, London, W.C.2, at 7-00 p.m.

20th NORTH EASTERN GRADUATE SECTION. An Address will be given by the President of the Senior Section, Mr. L. Walker, M.I.P.E., in the Neville Hall Mining Institution, Westgate Road, Newcastle-upon-Tyne, 1, at 7-00 p.m.

21st YORKSHIRE GRADUATE SECTION. A lecture on "History and Developments of the Diesel Engine" will be given by Mr. J. Whitaker, at the Great Northern Station Hotel, Leeds, 1, at 2-30 p.m.

23rd COVENTRY GRADUATE SECTION. A lecture on "Die Casting" will be given by Mr. Robinson, in the Greyfriars Rooms, The Geisha Cafe, Hertford Street, Coventry, at 7-15 p.m.

23rd HALIFAX SECTION. A lecture on "Production Management Problems" will be given by Mr. M. Seaman, M.Sc., M.I.Mech.E., A.M.I.E.E., M.I.P.E., at Whiteley's Cafe, Westgate, Huddersfield, at 7-00 p.m. This is a joint meeting with the "D.B.T." Engineering Society.

25th SHREWSBURY SUB-SECTION. A lecture on "Modern Die Forging Practice" will be given at the Walker Technical College, Oakengates, at 7-30 p.m.

25th SOUTH WALES AND MONMOUTHSHIRE SECTION. A lecture on "Starting a New Factory" will be given by Mr. A. R. Northover, A.M.I.P.E., at the South Wales Institute of Engineers, Park Place, Cardiff, at 6-45 p.m.

January—*cont.*

27th LIVERPOOL SECTION. A Ladies' Night will be held at Reece's Restaurant, Parker Street, Liverpool.

27th LONDON GRADUATE SECTION. A lecture on " Factors which Govern Productivity " will be given by Mr. Ian Mikardo, M.P., at the Institution of Production Engineers, 36 Portman Square, London, W.1, at 7.15 p.m.

30th MANCHESTER SECTION. A lecture on " Measurement of Productive Efficiency " will be given by Mr. W. C. Puckey, M.I.P.E., F.I.I.A., at the College of Technology, Sackville Street, Manchester, at 7.15 p.m.

30th NORTH EASTERN SECTION. A lecture on " Protective Finishes " will be given by Mr. A. Messenger, in the Neville Hall Mining Institution, Westgate Road, Newcastle-upon-Tyne, 1, at 7-00 p.m.

31st LINCOLN SUB-SECTION. A lecture will be given by Mr. S. Richards at Ruston & Hornsby's Canteen, Anchor Street Works, Lincoln, at 7-15 p.m.

31st LUTON, BEDFORD AND DISTRICT SECTION. A lecture on " Electronics in Industry " will be given by Mr. J. S. Sargrove in the Small Assembly Room, Town Hall, Luton, at 7-00 p.m.

MEASUREMENT OF PRODUCTIVITY

An Invitation to Members

Many members will know that a Joint Committee of our Institution and the Institute of Cost and Works Accountants has been working on this problem for many months. They have now published an Interim Report which is reprinted in the following pages.

It is believed that there are many small and medium firms in the country who have developed their own methods of measuring their productivity or productive efficiency. We consider that a more widespread application of first-class methods of measurement would be of considerable value, particularly amongst small and medium sized firms, and that this would do a great deal to increase national productivity.

The Joint Committee are particularly anxious to get in touch with firms of this category who feel that they have one or more methods of measurement which are unusual. Will any member who feels that he can give us such information please get in touch with Headquarters, so that the necessary introduction may be made.

Any information the Joint Committee receive will naturally be treated in the strictest confidence, and there is no suggestion whatever of publishing facts or figures relating to any particular firm's activities.

W. C. PUCKEY,
Joint Chairman, Joint Committee on Measurement of Productivity.

Composition of Joint Committee

MR. L. W. ROBSON } Joint
MR. WALTER C. PUCKEY } Chairmen

MR. B. H. DYSON

MR. R. W. DOBSON

MR. C. E. A. GRIFFIN, O.B.E.

MR. IAN T. MORROW

MR. S. J. D. BERGER, M.C. (Director, I.C.W.A.)

MAJOR C. B. THORNE, M.C. (Director and General Secretary, I.P.E.)

The Committee is working in close association with the Anglo-American Council on Productivity, U.K. Section, through Mr. R. G. Hooker.

Note:—*Copies of this Report are obtainable from the sole distributors, Messrs. Macdonald & Evans, 8, John Street, Bedford Row, London, W.C.1. Price* 1/6. (1/7 *post free.*)

INTERIM REPORT ON MEASUREMENT OF PRODUCTIVITY

1 On November 5th, 1948, a one-day Conference on the Measurement of Productivity was held in London. It was organised jointly by the Institution of Production Engineers and the Institute of Cost and Works Accountants, and attended at short notice by a large number of members of both organisations from widely separated areas. Discussion at the Conference was so enthusiastic that it quickly became obvious that the matter could not be allowed to rest without further action. The question of productivity was a matter of national importance, and it was clear that the professions represented by the two organisations were eminently qualified to make a contribution and were anxious to do so.

2 As a direct result of this Conference, a Joint Committee of the two organisations was set up in January 1949, with the objects of (a) devising the best means of measuring comparative productivity, and (b) of applying these methods for the purpose of increasing productivity.

3 Since that date much work has been done by the Joint Committee. The Joint Committee report that their efforts have been concentrated in the first instance on research into existing techniques of measuring productivity. As in most research, some unexpected facts were revealed which should be of interest to industry as a whole. These were :

(*a*) The lack of knowledge of machine utilisation in British industry. It is clear that machine utilisation is low, and that if this were improved it would make a significant contribution to increased productivity.

(*b*) The lack of cost and statistical information available at supervisory level. Very often through poor presentation and lack of understanding, much of the existing information is ineffective.

(*c*) The serious lack of agreed principle in the application of time study methods. Present time study standards suffer in most cases from serious deficiences for the purpose of

comparison between departments and firms. If uniformity were introduced into the methods of arriving at such standards, valuable data would be available.

4 The Joint Committee are convinced that a common measurement of productivity should be available to management for the improvement of productivity, and should, at the same time, be simple enough to be grasped and used by departmental foremen.

5 The Committee fully realise that there is still a great deal of work to be done since the investigations undertaken so far have revealed many difficulties and complexities inherent in the problem of determining a standard of measurement. In attempting to codify the various aspects of the problem and to evolve some practical methods of solving it, however, the Joint Committee feel that they have at least covered some essential ground-work on which any future extension of their work will be based.

6 **PREVIOUS WORK** The first task of the Committee was obviously to examine any work previously carried out on the measurement of comparative productivity, but it soon became clear that the field was practically virgin. Some economists—notably Laszlo Rostas and Colin Clark—had carried out comparative studies of productivity in different countries and in the same country at different periods, using national statistics of output, but these were of far too general a nature to be of value to management or to the man on the shop floor. They were, in particular, useless for comparing processes and operations within a single firm or between different firms.

7 In the field of industry, many firms have their own standards of measuring their productivity, but these, whether a manufacturing price, a factory cost, or a standard cost, inevitably refer to a finished product, and cannot be used as a comparison of the efficiency of different departments responsible for only a part of the manufacturing process. Nor can they be used for inter-firm or inter-industry comparisons, since, for instance, an electric motor produced by firm A is a different product from an electric motor produced by firm B. The two firms may be manufacturing to meet an entirely different market, and even where the two products are practically identical, the ratio of " bought out " to manufactured components may vary widely. Comparative assessment of productivity on the basis of product is thus impossible, but the possibility of comparing productivity on the basis of process remains.

8 Product may be defined as the item actually produced. It may be the industrial component from a machine shop, the finished drawing of a designer or a complete assembly such as a radio or a ship. Process may be defined as a specialised activity which may be used by companies making various products. The process of milling, for instance, is common to an automobile factory or a shipyard, to a toolroom or a machine shop. The process of internal transport is common to all factories and the process of typing to all offices. A variety of processes is almost always necessary to produce any product, and by switching attention from product to process a greater range of comparison becomes possible. Many processes are common to firms making totally different products, so that unlike factories can compare efficiencies. By the relation of the many processes necessary for the production of a particular product to a common standard, it may well be possible to arrive at some definite conclusion regarding the productivity of the firm as a whole, and eventually of the industry as a whole. (*see Appendix A*)

9 This emphasis on processes rather than product is also more in line with the thinking of the departmental head or foreman. Indeed, one great advantage of process measurement is that standards of comparison can be set for use, not only by top management, but by all grades of supervisors, foremen and individual workers.

10 **PLANNING THE EXPERIMENT** Working on these lines, the Committee asked for and obtained the co-operation of four prominent companies in the London area in an experimental investigation into relative levels of productivity in a single process. A condition of the co-operation was that the firms should remain anonymous, but it may be said that they are among the leaders of their industries. Each firm has its own Production Engineering and Cost Accountants' Department, and management techniques are well in advance of standard practice.

11 Preliminary investigation showed that all four firms were already compiling statistical data with the aim of comparing their productivity over time, but that the methods employed varied so widely as to preclude the possibility of comparison without further data. A particular process common to all four firms was therefore chosen, and a departmental efficiency statement was prepared (*see Appendix B*) which would include all the data the Committee considered necessary to realise a common basis of comparison. The process chosen—the operation of a group of automatic lathes—was deliberately selected for its simplicity, but the Statement was elaborated to include data that might be necessary for more

complicated comparisons, since it was hoped to extend the work later to further processes where these details might be necessary.

12 The Statement consists of two parts, headed Forecast and Actual, the Forecast section being filled in at the beginning of each period with budgeted or estimated figures, and the Actual being filled in at the end of the period with the corresponding figures obtained in practice. Each section is again divided into five sub-sections, covering Plant Utilisation, Running Efficiency, Cost, Cost Efficiency and Performance.

13 The co-operating firms put this statement into use during July and August, 1949, in their Automatic Departments for a period of four weeks, the necessary figures being obtained as far as possible at supervisor's level by the Production Department in collaboration with the Cost Accountant in each case.

14 **PLANT UTILISATION** One obvious factor in productivity is the extent to which the capital equipment of a firm is actually used, and the first section of the statement aimed at obtaining comparative figures on this point. The first column showed the maximum hours which could be worked by the department, and was obtained by multiplying the number of machines by the number of hours in the working week. Some allowance must obviously be made for shut-down periods caused by routine operations such as setting, lubricating and general service, and firms were asked to give their estimates of the number of hours to be allowed for this purpose.

15 The results were somewhat startling. The estimate of shut-down time, based on a percentage of capacity hours, varied widely, from 10 to 20 per cent. These very considerable discrepancies suggested that, even in the simplest possible case, the firms experienced great difficulties in forecasting plant utilisation, and that any estimate might be subject to an error of as much as 10 per cent.

16 The attainable capacity of the firm was obtained by deducting the relaxation allowance from the total capacity hours, and the normal productive hours calculated by making any further reduction necessary for lack of orders, special operations, etc. Finally, the percentage utilisation of capacity was calculated by expressing normal productive hours as a percentage of capacity.

17 As might be expected, the percentage utilisation of capacity showed very considerable variation both between firms and between consecutive weeks for the same firm. From the returns received, it was clear that, in general, plant utilisation was low; in one case it was as low as 69 per cent. The Joint Committee feel that this was one of

the most significant facts brought to light by the investigation. A study limited to machine utilisation throughout British industry should, they conclude, provide valuable information, for if machine utilisation of the less efficient firms were brought up to the level of the best, there would be a very considerable increase in productivity at very little extra cost.

18 **COST AND COST EFFICIENCY**

The calculation of activity in terms of hours worked will give a measure of comparative productivity between two departments of an identical nature, but such identity rarely occurs. The output of any process depends both on labour and machinery and the ratio of investment in these two factors will vary from firm to firm. Comparisons of crude output per man-hour or per man-year for a given process will be useless unless they can take into account the variations in the degrees of mechanisation of the department concerned, but the only unit in which this can be done is that of money, i.e. in earnings of labour and depreciation and maintenance costs of machinery. It is here that the Cost Accountant makes his contribution, because he is able to translate all expenditure of resources into the common language of money. This, applied to the standard hours produced, will give a cost per standard hour, which, in time, could possibly be adjusted to a standard hour for the industry.

19 The sub-sections dealing with cost and cost efficiency were concerned with an effort to discover a money cost per standard hour for the process that would eliminate factors specific to the firm and enable a direct comparison of productivity to be made between the firms. Unfortunately, the initial attempt did not provide sufficient data for even a tentative comparison to be made.

20 No attempt was made beforehand to define what expenses should be included as costs in the process, as it was felt that practice would vary so widely that it was better to ask the firms to put in their own ideas on the cost, and co-ordinate their figures during the analysis of returns.

21 The preliminary investigations showed that Cost Accountants might assist Management far more effectively if they were to present costing and statistical information in such a way that both management and supervisory staff could know the cost of running a process rather than the end cost of a product. The Accountants concerned had accepted it as a matter of duty that they ought to assist Management, but both Accountants and Management needed to study each other's problems before the statistical information presented to Management was satisfactory.

22 **RESULTS OF EXPERIMENTAL SURVEY**

After the completion of the departmental efficiency statement, the Joint Committee invited representatives of the Production and Accounting Departments of each of the firms concerned to attend a meeting to discover :

(*a*) Whether the statement was sufficiently simple to be understood at supervisory level,

(*b*) Whether the same information could be obtained by any simpler means, and

(*c*) Whether the companies concerned had found it of any practical value.

It was agreed that the statement was not simple enough in its present form, but the firms concerned all felt that this sort of information was necessary and had similar methods of obtaining it within their own organisation, though in some other form. One interesting result that emerged from the discussion was the fact that each firm thought it had a special problem, whereas on examination, most of the individual difficulties were found to be common to all. The main advantage derived to date has been a psychological one, in that the survey proved, even to large and efficient firms, the need for a study of productivity in all its angles.

23 **TIME STUDY INVESTIGATION**

One of the major difficulties encountered in the experiment was the difficulty of assessing the "standard hour", owing to the differences in methods of payment for labour between the firms. The Joint Committee consequently decided to set up a Time Study Sub-Group to investigate Work Measurement and methods of Time Study in collaboration with five prominent firms.

24 It was found that even with processes the standards set varied from piecework prices for a complete job to time standards for a single operation, these standards being arrived at from " guesstimates ", past performances, calculations, time study observations, or element time recording. The Sub-Committee found that methods of setting standards were greatly influenced by the type of product manufactured. The heavy engineering industry lends itself more readily to rate fixing, whereas light engineering, with its short operational times and high degree of repetition, is more suited to time and motion study. Rate fixing, however, while in common use as a method of calculating payments due to labour, cannot be used for comparing efficiency and measuring productive effort, owing to the changes in the value of money

from time to time and the existence of differing national monetary units. Comparisons of this nature can only be carried out in terms of time, since time is an international standard and the unit of time—hour, minute or second—never varies over any period.

25 **VARIATION IN TIME STUDY METHODS**

The normal time taken to complete any production operation is not, however, an absolute standard since much depends on the worker undertaking the operation. In time study practice, the normal time allowed for the operation is built up of two parts,

(*a*) the recorded time—i.e. the minutes and seconds recorded by stop watch observation (or, on occasion, synthetic times based on past study), and

(*b*) the time study engineer's assessment of the effective speed and effort put into the work by the particular operator under observation.

The latter will of course vary, and the Sub-Group's investigations suggested that these variations were considerable, both within the various firms observed and also between individual time study engineers. As a check, a time study engineer from each of the five selected firms studied three jobs under identical conditions, and the variation of their speed and effort rating was 12 per cent. (*see Appendix C*). Nor did the variation end here, since the basic time recorded by the time study engineer was so loaded with allowances that it was invariably useless for comparative measurement. These allowances varied with every individual firm to cover fatigue, relaxation, personal needs, cleaning down, tea breaks and so on.

26 The variation of allowed time for the same factor also varied widely, for example, fatigue allowance varied from 7 per cent. to 20 per cent. of the recorded time on an identical job under identical conditions. (*see Appendix D*).

27 **WAGE POLICY ALLOWANCES**

An additional and even more serious problem encountered was the allowance added to build up the time standard to an attractive wage-earning level. This wage policy allowance was variable within each firm and was sometimes not even officially acknowledged as such, but was introduced to the time study rate as a "padding" to the time study engineer's speed and effort assessment or to any of the other ancillary allowances mentioned. In fact, in the majority of firms, time study rates are not used as a standard of measurement but as a method of bolstering up a basic hourly

wage to an attractive wage level, under the title of an incentive scheme. If therefore industry requires a standard of measurement of productivity, each firm would have to state clearly its basic rate plus its additions for wage policy, or, alternatively, would have to accept an index whereby its time study rates would be brought to a common denominator.

28 The Time Study Sub-Group, therefore, suggests that

(*a*) Factory costs or piecework processes are not satisfactory as a standard of measurement of comparative productivity between factories.

(*b*) Time study standards are the most suitable starting point for comparing productivity, since time is an internationally recognised standard.

(*c*) It is believed, however, that few firms now use comparable time study methods or standards and the great majority of time study rates are inconsistent, both in the time allowance for each factor and the content of allowances for extraneous factors.

(*d*) In the main, firms do not compute or use their time study rates as a standard of measurement, but as a means of presenting an attractive wage level, and if time study rates are to be used to compare productivity, firms must either revise their present wage level rates, or show their basic rate plus their addition for wage policy.

(*e*) A research programme is necessary to define recommended standard allowances, a task which might well be undertaken by some such body as the British Standards Institution.

(*f*) A unified system of training for time study engineers, sponsored by the Ministry of Education, and a uniform terminology for time study engineers, are essential.

29 **ACKNOWLEDGEMENT** Finally, the Joint Committee wish to record their great appreciation of the co-operation and assistance rendered by the collaborating firms during their preliminary investigations. Such co-operation will be invaluable in the future, when the Committee propose to follow up the promising lines of research suggested by these initial explorations, and to extend the scope of their investigations over a wider field.

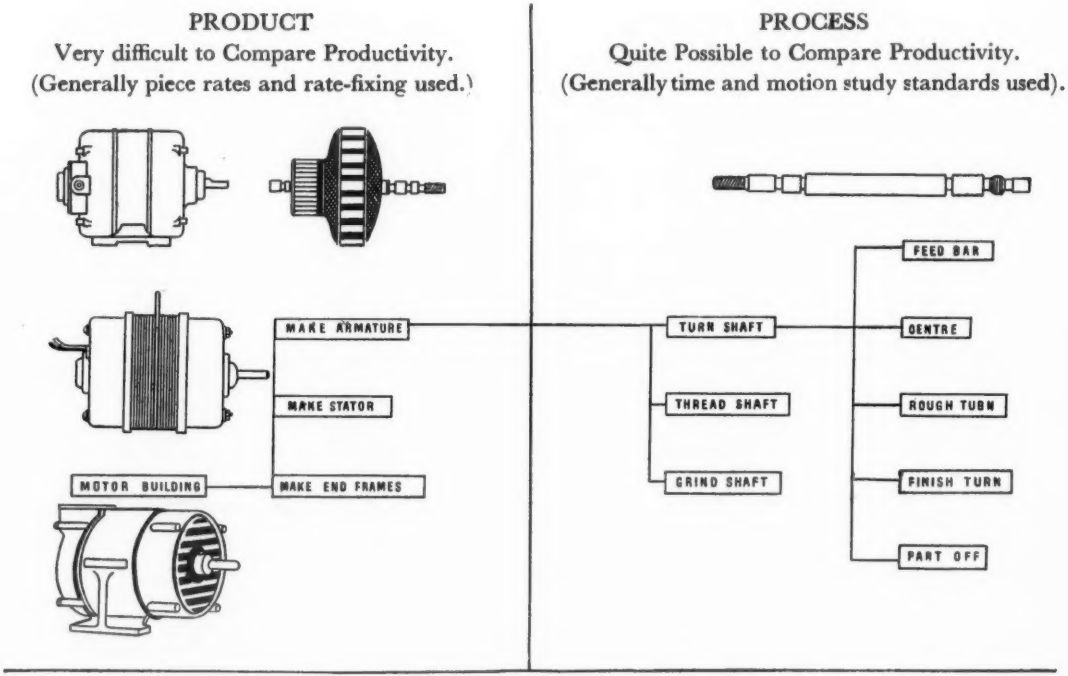
PRODUCT
Very difficult to Compare Productivity.
(Generally piece rates and rate-fixing used.)
PROCESS
Quite Possible to Compare Productivity.
(Generally time and motion study standards used).
MAKE ARMATURE
MAKE STATOR
MOTOR BUILDING
MAKE END FRAMES
TURN SHAFT
THREAD SHAFT
GRIND SHAFT
FEED BAR
CENTRE
ROUGH TURN
FINISH TURN
PART OFF

FIG. 3.

1. FORE CAS

PROCESS	UTILISATION: CAPACITY HOURS	UTILISATION: RELAXATION	UTILISATION: ATTAINABLE CAPACITY	UTILISATION: NORMAL PRODUCTIVE HOURS	UTILISATION: % OF CAPACITY	RUNNING EFFICIENCY: BUDGET STANDARD HOURS	RUNNING EFFICIENCY: % OF NORMAL	TOTAL BUDGET COST	COST
Col. 1	Col. 2	Col. 3	Col. 4 = 2 − 3	Col. 5	Col. 6 = 5 ÷ 4 × 100	Col. 7	Col. 8 = 7 ÷ 5 × 100	Col. 9	Col. 10
A group of like machines or work-people performing a like operation.	HRS. The maximum hours which a machine can work i.e., if a factory is open for 44 hours per week the capacity hours for one machine are 44 hours.	HRS. The amount by which capacity is reduced to cover setting-up maintenance and like unavoidable losses.	HRS. The number of hours during which the machine ought to be able to work provided there are sufficient orders and materials available.	HRS. The hours during which it is forecast or expected that the machine will work. This may be the same as attainable capacity or less. If it is less, the difference is due to a reduction in the use of the machine through lack of orders or through plant being out of balance, or the machine covering special operations.	% The ratio of expected or forecast production hours to Attainable Capacity.	HRS. The budget or forecast standard hours, or hours-worth of work which should be produced by the process.	% The ratio of Budget standard hours to normal or forecast productive hours.	£ The agreed expenditure at the forecast activity for direct labour, indirect labour and other costs under the control of the departmental manager or foreman.	An analysis of the actual expenditure under the same headings as the budgeted cost.

2. ACT UAL

PROCESS	UTILISATION:	UTILISATION:	UTILISATION:	UTILISATION: PRODUCTIVE HOURS	UTILISATION: % OF NORMAL	RUNNING EFFICIENCY: STANDARD HOURS	RUNNING EFFICIENCY:	TOTAL STANDARD COST	COST TOTAL ACTUAL COST
Col. 1	Col. 2	Col. 3	Col. 4	Col. 5	Col. 6	Col. 7	Col. 8	Col. 9	Col. 10
A group of like machines or work-people performing a like operation.				HRS. The hours during which the machines or work-people have actually worked.	% The ratio of productive hours to norma productive hours, i.e. Col A 5 / Col F 5	HRS. The total standard hours actually produced in the period under review.		£ The standard value of the work done i.e. Col A 7 × Col F 13	£

DIX B.

CAST

COST		COST EFFICIENCY						
Col. 10	Col. 11	COST PER NORMAL HOUR Col. 12 =9÷5	COST PER STANDARD HOUR Col. 13 =9÷7	STANDARD HOUR INDEX Col. 14	ADJUSTED COST PER STANDARD HOUR Col. 15 =13÷14	Col. 16	Col. 17	Col. 18
£		£	£		£			
The agreed expenditure at the forecast activity for direct labour, indirect labour and other costs under the control		The expected or budget cost per hour.	The expected expenditure per standard hour.	The ratio put on the process standard hours by the Production Engineer when comparing the standard hours with the master standard hours.	The cost of the process in terms of the master standard hour.			

UAL

COST		COST EFFICIENCY				PERFORMANCE		
TOTAL ACTUAL COST	TOTAL VARIANCE	COST PER PRODUCTIVE HOUR Col. 12 =10÷5	COST PER STANDARD HOUR Col. 13 =10÷7	STANDARD HOUR INDEX	ADJUSTED COST PER STANDARD HOUR Col. 15 =13÷14	% ACTIVITY	% EFFICIENCY	% OF CAPACITY USAGE
Col. 10	Col. 11 =9−10			Col. 14		Col. 16	Col. 17	Col. 18
£	£	£	£		£	%	%	%
An analysis of the actual expenditure under the same headings as the budgeted cost.	The difference between the total standard cost and the total actual cost.	The actual money spent in the department per productive hour.	The total actual cost divided by the standard hours produced.	The ratio put on the process standard hours by the Production Engineer when comparing the standard hours with the master Standard hours.	The cost of the process in terms of the master Standard hour.	The measure of the rise and fall in the volume of work done i.e. $\frac{\text{Col A 7}}{\text{Col F 7}}$	The output per actual hour compared with the forecast output per hour, i.e. $\frac{\text{Col A 7}}{\text{Col A 5}} \times \text{Col F 8}$	The ratio of productive hours to normal productive hours, i.e. $\frac{\text{Col A 5}}{\text{Col F 5}}$

APPENDIX C.

NORMAL TIME.

Varying Speed and Effort Rating Allowances given by Time Study Engineers from 5 different firms while studying identical jobs.

Firm A.

AVERAGE RECORDED TIME	Speed and Effort Rating

Normal Time

Firm B.

AVERAGE RECORDED TIME	Speed and Effort Rating

Normal Time

Firm C.

AVERAGE RECORDED TIME	Speed and Effort Rating

Normal Time

Firm D.

AVERAGE RECORDED TIME	Speed and Effort Rating

Normal Time

Firm E.

AVERAGE RECORDED TIME	Speed and Effort Rating

Normal Time

NORMAL TIME—Recorded Time modified by Speed and Effort ating of Individual Time Study Engineers.

APPENDIX D.

TIME ALLOWED FOR OPERATION.

Varying Allowances given by Time Study Engineers from five different firms on Normal Time. Owing to varying Wage Policies of firms these allowances are approximate only.

Firm A.

NORMAL TIME	Personal

Time Allowed for Operation

Firm B.

NORMAL TIME	Fatigue

Time Allowed for Operation

Firm C.

NORMAL TIME	Wage Policy

Time Allowed for Operation

Firm D.

NORMAL TIME	Fatigue	Wage Policy

Time Allowed for Operation

Firm E.

NORMAL TIME	Lost Time	Tea	Personal	Cleaning & Delays	Fatigue

Time Allowed for Operation

SHEET METAL AS A SUBSTITUTE FOR OTHER MATERIALS

By J. A. GRAINGER, A.M.I.Mech.E., A.M.I.P.E. *

To be presented to the Luton, Bedford and District Section of the Institution, on December 20th, 1949.

One of the most revolutionary of modern machine tools is the power press and since its invention many developments and improvements in design have taken place in the endeavour to make it as universal a tool as possible, and to extend the use of presses to the manufacture of as many types of article as can be designed for manufacture from sheet metal.

Presswork is a comparatively new or modern process, which was primarily introduced for the working of sheet metal—mainly in the cold state. Hot working of metal is hardly ever encountered in the normal type of high production press shop—for it is not until the metal becomes of the thickness of $\frac{3}{16}$ in. or so that hot working becomes necessary. That is to say, hot working is very uncommon on sheet metal, but is quite normal practice on "plate." Thus the use of hot working is more or less the prerogative of the heavy industries such as shipbuilding, boiler making and similar types of work such as parts for rolling stock.

RAPID ADVANCES IN TECHNIQUE

The advances made in the technique of pressing sheet metal in the more recent years have been very great indeed, and undoubtedly the pioneers and inventors of power presses had no idea of the rapid strides that would be made, nor the variety of uses to which press work would eventually be put. To them the limits of accuracy demanded, and maintained, at the present time would also have probably appeared to be impossibilities.

Production rates obtained by modern machines and tooling are of such proportions as to bear no comparison with those generally accepted in the not so very distant past.

Presswork and the use of sheet metal as known to us can be said to be a comparatively new process, the use of the latter having increased as the efficiency of the former has improved. The possibilities before this new method of altering the form of sheet metal soon became apparent and the use of both presses and sheet metal has extended rapidly. Just as presses, on their side, have extended to

* *Superintendent, Sheet Metal Division A.C., Sphinx Spark Plug Co., Division of General Motors Ltd.*

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other fields of application such as hot and cold coining, extruding, forging, moulding, forming, assembling, broaching, deep drawing, etc., so has sheet metal extended its field of application. Many products are now being made from sheet metal which were originally manufactured from other materials, or by other methods. One of the greatest single factors having a marked influence on the development or extension of the use of sheet metal is, of course, the advent of the automobile. Since the invention of the motor car, the use of presses and presswork has increased rapidly, both in this industry and in other directions such as the production of domestic holloware, office furniture, etc. Considering the extensive application of presswork at the present time, and its even greater application in the future, one is tempted to wonder how industry would fare under existing industrial conditions and production requirements if the art of cold pressing of metals was unknown.

From the foregoing it is fairly obvious that the two items, presses and sheet metal, go hand in hand and together they are used for the rapid, accurate and economical production of many articles, at very high rates of production, which would otherwise have to be made by other methods at greater cost.

CASTING AND FORGING

Perhaps the two methods of production which have offered the greatest opportunities to the sheet metal and press technician are those of casting and forging. Apart from the fact that the articles produced under the press are cheaper, in most instances, there is the fact that sales value is in almost every case increased, as the appearance of the article is much more pleasing.

Sometimes an article has to be made from sheet metal as a substitute for other materials or methods for none of the reasons given above. For instance, during the war many articles were made from sheet metal, sheet steel in particular, as the usual material was in short supply due to the fact that it had to be diverted to more urgent use, or that it was imported and enemy action on the high seas kept it in short supply. Other reasons for the use of sheet metal instead of other materials are :—

(1) The question of weight, which can be kept low by use of a suitable gauge of material ;

(2) Strength, as very often the article can be made both lighter and stronger by incorporating suitable flanges or ribs in the design ;

(3) For functional reasons, such as the freedom from porosity in a drawn article, porosity being an ever present danger in a cast article.

Whereas it was the practice a few years ago first to think of casting or forging when designing a new product it is now the practice first to think of pressing from sheet metal, with casting or forging coming in as a poor second choice. This is possibly due to the fact that, apart from the factors mentioned earlier, most factories possess a press shop of their own, whereas the number of factories that include a foundry among their departments is very much smaller. Likewise, the number of contract press shops at the disposal of those firms in search of outside aid is much greater than the number of either iron or non-ferrous foundries, including die-cast foundries.

SHEET METAL AS A SUBSTITUTE

When considering the use of sheet metal in place of other materials, there are many aspects to be considered ; not only the aesthetic aspect, nor the question of production economies alone will be the deciding factor or factors. It is quite probable, and even possible, that the question of strength will enter largely into the picture at some time during deliberations. In a considerable number of cases too, it will probably be found that no difference, or at least only a very small difference, in cost will be shown when the comparative methods of manufacture are considered and estimated. It may even be that the figures in a small number of cases show up unfavourably for the sheet metal product. When this condition does arise, it may not be quite such a bad thing as it appears on first sight. Even though an adverse picture is presented in the first instance, further investigation may prove in fact that the reverse is the actual case. This state of affairs can arise and, in fact, has actually arisen, in the experience of the author, due to a high and unexposed scrap content due to the original method of manufacture. It may even expose this latter condition when there is a saving shown in the first instance.

One item which may be cited as an instance of this is in the production of domestic holloware. When the electric cooker became very popular with housewives, the use of properly designed hot plate utensils increased rapidly. As everyone knows, this type of cooking utensil is designed with a thin wall of, say about 10 gauge thickness, while the bottom is much thicker, usually about $\frac{5}{16}$ in. This, of course, is done so that the bottom will not distort under the repeated application of heat and will, in consequence, retain its efficiency for the whole of its useful life, due to a close all over surface contact with the hot plate to ensure quick heat transference to the contents of the utensil.

As aluminium and a number of its alloys were already popular for the manufacture of saucepans, kettles and such like articles, by this time it was very natural that those materials should be chosen for the new type of cooking utensil demanded, particularly as they

were extremely good conductors of heat. In the first instance, it was assumed that the alloy that must be used would need to be one of the harder of the range to withstand hard usage and hard knocks. It was usual, therefore, to use one of the aluminium-silicon alloys, such as " Y " alloy. The method chosen for the manufacture of the articles was casting by the gravity die cast process. This was, in fact, the only way satisfactorily to produce articles from this material. In production, however, it was found that excessive scrap resulted, owing to the incidence of innumerable minute pinholes or blowholes in the thick bottom, and also where the runners and risers were sawn off. These pinholes, however, did not become visible until after the base of the article had been disc ground, and even then all holes were not exposed, and a laborious and slow inspection had to be carried out with a small sharp-pointed instrument similar to a scriber, in order to find by physical means those holes which were covered by a very thin film of metal.

To produce a saucepan or a frypan by the gravity die-casting process was, as will be seen, a rather lengthy, slow and fairly costly process. The actual operations involved in making one of these products by this method were :—

(1) Cast
(2) Saw off runners and risers
(3) Fettle
(4) Disc grind bottom face
(5) Visually inspect for pinholes
(6) Grind outside face
(7) Scratch brush all over, inside and out
(8) Physically inspect for pinholes beneath surface

In addition to these, there were the operations necessary for making ready for casting ; these were :—

(a) Heat up casting dies to casting temperature in gas fired muffle furnace
(b) Coat die cavity with die coating
(c) Connect water cooling pipes to trunnion base
(d) Assemble die members and cores
(e) Obtain molten charge from bale-out furnace

Of these, (a) and (c) would possibly need to be performed at the beginning of each shift only, according to the speed at which the operator worked so as to retain the heat in the die ; (b) would need to be performed about three or four times per shift, and (d) and (e) would have to be carried out for each and every product cast. It

will at once be seen, therefore, that an extremely fast operator would, at the best, produce only two or three hundred castings in an eight-hour day, of which perhaps only 75 per cent. were good.

Under these conditions, can it be wondered that some other means of producing the same article was sought? The aim in this search was to find a method by which an article of at least as good performance in service would be produced more quickly, of better quality (from the reject point of view) and of as pleasing an appearance, at the same or less cost to the purchaser. It needed but little consideration before the production of this particular type of article from thick sheet aluminium was seen to offer very great possibilities. This is now more or less the standard method in use in the holloware industry for hot plate utensils, although a certain amount of cast work still takes place. This, however, is usually confined to such articles as kettles which are produced by one of two methods, either (a) casting in a sand mould or (b) casting in a gravity casting die using sand cores.

TECHNIQUE OF PRESSING

To return to the pressing technique. The operations required here are :—

(1) Draw and iron
(2) Reduce and iron wall
(3) Trim top edge
(4) Disc grind or coin bottom
(5) Polish

No mention is made of cutting the blank from thick sheet as it is very often the practice to purchase the round blanks already cut direct from the aluminium rollers.

The first two operations may in some cases be insufficient to produce an article of sufficient height of wall or of thin enough section. In such cases it may be necessary to institute a further reducing and ironing operation. However, as production from these operations would be in the region of 300 per hour, the production is still at the rate of 100 articles per hour as compared with the casting process. The resultant article too has as good an appearance and will give as good service in use.

The bulk of the work in the production from thick sheet is done during the press operations. The actual inside diameter of the saucepan is obtained during the first drawing operation, the subsequent press operation being ironing operations for the purpose of thinning down the walls and increasing the height. This is done by the use of stepped dies which make several reductions at one pass through the die.

To give a further example of a product in which an aluminium alloy casting was replaced by a steel pressing, let us take the case

of the bracket shown in Fig. 1. When this particular product was first produced, it was to the design and specification of the customer, the material being specified as aluminium-silicon " Y " alloy. This particular product had to withstand fairly severe and arduous service, being the bracket for attaching a well-known child's side-car to tandem pedal-cycles.

FIG. 1. Bracket produced from 10 S.W.G. mild steel sheet to supersede the original, which was cast in aluminium-silicon alloy and which failed in service.

After several hundreds of the cast frames had been manufactured and put into service, disturbing reports were received regarding fatigue failure and concern was felt lest more serious results might ensue. The bracket was therefore taken out of production and the customer put out enquiries for a pressed steel frame, the stipulation being made that the successful contractor should design the product, which need not be of the same shape as the casting, always providing that the main attachment points were dimensionally and positionally reproduced. The product shown was the result of many hours of intensive deliberation and calculation of stresses and bending moments. As the casting alloy was one of the harder and more brittle range, it was a feature of the original design of casting to have a fairly generous " L " section with reinforcing ribs at suitable points. The pressed substitute was from 10 S.W.G. mild steel of deep stamping quality. Weight for weight, therefore, there was very little difference in the two products. The steel pressed product, however, when prototypes were put on test, proved entirely satisfactory and more than adequate for the arduous service which it was called upon to undergo.

Not only was the bracket itself made as a pressing, but the caps for the bearings, the bearing liners and the eyebolt retainers were made from sheet metal. The bearing caps and eyebolt retainers were made from the scrap surround and the piercings from the manufacture of the bracket itself, whilst the bearing liners were produced from 70/30 brass sheet in the fully annealed condition. A comparison of the operating sequence for the alternative methods of production will probably be of interest in the case of this product also. For the cast product we have :—

For bracket :—

(1) Cast
(2) Saw off runners and risers
(3) Fettle
(4) Inspect for porosity
(5) Mill slots for cap hinge
(6) Drill hinge pinholes
(7) Ream hinge pinholes
(8) Drill eyebolt holes

For bearing caps : 2 off for each assembly :—

(1) Cast
(2) Saw off runners and risers
(3) Fettle
(4) Mill cheeks of hinge lug
(5) Drill hinge pinhole
(6) Ream hinge pinhole

Final operations consisted of fitting and assembling the bearing caps and hinge pins and then boring the two bearing journals to ensure lineability.

In addition to the above, there were also the operations previously mentioned as being necessary for making ready for casting. The rate of casting in this instance would be somewhat higher than in the former case, say up to 500 per 8-hour day. The operations of milling, drilling, reaming, and boring were all comparatively slow.

PRESSINGS AND CASTINGS

How did the sheet metal pressed product compare with the cast product ? Let us analyse the operations that were necessary to produce by this method. In this case we have the following :—

For the bracket :—

(1) Emboss strengthening ribs
(2) Blank
(3) Pierce lightening holes, fixing slots and centre hole

(4) Raise
(5) Flange edges, holes and raise hinge lugs
(6) Pierce hinge pinholes
(7) Pierce eyebolt holes

For the caps :—

(1) Blank and pierce from scrap
(2) Raise and emboss

For the eyebolt retainers :—

(1) Blank and pierce from scrap
(2) Raise

For the liners :—

(1) Crop and pierce
(2) Raise

The final operations consisted of assembling the eyebolts and retainers and riveting ; assembling and riveting bearing liners ; assembling bearing caps and hinge pins.

The total number of operations by each method, therefore, was as follows :—For the cast product, 25 excluding the making ready for casting procedure. For the pressed product 25 again, but in the latter case there were no making up operations necessary, although these would be partially counterbalanced by the necessary tool-setting. Production, however, by the latter method was much greater as it was possible to produce from the slowest press operation at the rate of approximately 200 per hour.

In the case of this product it will at once be seen that not only was the result a better product from the point of view of functional properties, but it was rather more pleasing in appearance on account of the more generous curvature and the more flowing lines of the contour. Finally, and perhaps almost as important as the safety aspect, was the fact that the rate of production was greatly increased and the price to the consumer was reduced.

These two items, then, are examples of two of the stated reasons for substituting sheet metal for other metals or methods of production, viz., reduction of scrap with increased production and secondly for functional reasons, incorporating safety as one aspect of function. A further reason was mentioned, viz., the absence of the original material from which the article was intended to be manufactured. To continue the procedure of illustrating the point with actual quoted examples, let us consider in this case the production of a petrol tank filler cap which was produced in large quantities before the war (and at the present time) by the pressure die casting process, using zinc base die cast alloy as the material.

During the war many thousands of these filler caps were required for use on Army vehicles, but the material from which they were produced was both in short supply and in demand for more important applications in the armaments programme. It was imperative, therefore, that some other method of manufacture should be found in order to conserve stocks of valuable zinc-base alloy. Again the choice fell on fabrication from sheet metal, and again the material chosen was sheet steel, mild steel of deep drawing quality in two gauges, 18 gauge for the cam ring and 20 gauge for the cap proper. The cast and pressed products are shown side by side in Fig. 2. To produce this particular item from sheet metal was one of those instances where the result was to increase the cost. In the national emergency, however, this was of secondary importance, although obviously it was necessary to keep production costs as low as possible. Naturally, as soon as possible after the cessation of hostilities, when the original material became in more free supply, the substitute method and material were discontinued and production reverted to the original method.

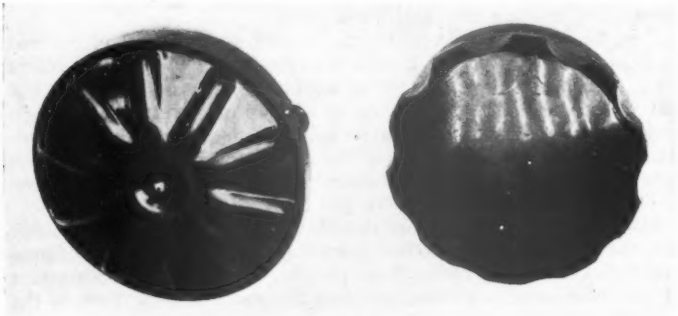


FIG. 2. A petrol tank filler cap produced by fabrication from mild steel sheet in order to conserve die cast alloy. The pressed article (ribbed) and the original cast one are shown side by side.

ECONOMICAL CONSIDERATIONS

It must not be assumed, however, that either gravity die casting or pressure die casting are the only two casting methods for which substitutes are sought. In fact, it is fairly true to say that if quantities are extremely large, pressure die casting will always prove to be cheaper than pressing from sheet metal, all other things being equal. There is one method of casting, however, over which the pressed metal method will always show a very great saving should the product be capable of production by that means, and that is sand casting.

It will be noted that the statement is made " should the product be capable of production by that means." This must always be borne in mind, for there are certain articles which by virtue of their shape or complexity will only be capable of production by the process of casting. It is here that one often hears the remark that the product could be made of sheet metal by fabricating from several pressings spot-welded together. This may be so, but the question arises, " Is it an economical proposition ? " To produce two, three or more parts by pressing entails the provision of a fairly large number of press tools which can in themselves be a fairly costly item. Then again the assembly of the several pressings may entail the use of locating fixtures for welding which could slow the job down so that the fabricated article in the end may prove to be not worth while.

On the other hand, should the product, as a casting, require a number of machining operations in order to maintain dimensional accuracy, or to provide location faces for use in the finished manufactured article, then it may well prove that the fabricated product would show a reasonable saving and prove the better method. This may be so, for pressings are capable of production to quite close limits which in all probability would render machining totally unnecessary.

USE OF LOCATING JIGS

The point was made regarding the probable use of locating jigs for welding. This is a point which is often overlooked when designing pressings that have to be assembled together. Too often the product designer thinks only of the ultimate function of his brain child, and totally forgets, or ignores, the production people on the shop floor who are responsible in the end for quality and production costs. If it is at all possible, and it is surprising in how few cases it is not, the parts should be designed in such a way as to be self-locating and so dispense with any external appliance at all. A little consideration will reveal the reason for this : the actual time taken up by the spot-welding is extremely small, in fact it may well be that each spot only takes between 4 to 7 cycles, that is to say from 4/50 to 7/50 of a second. Should two pieces require, say, 6 spot-welds to fasten them securely, the actual welding time is then only $\frac{3}{4}$ of a second at the longest weld cycle ; if we allow $\frac{1}{2}$ a second to move from spot to spot, we have another 3 seconds or a total of $3\frac{3}{4}$ seconds—say 4 seconds. Should it be necessary to use a locating jig, it will be unusual if the operator is able to assemble the parts with it, ready for welding, in under 6 seconds, which is one and a half times as long as the operating time.

It is fairly obvious then that if the parts are self-locating, the greater part of this 6 seconds will be saved and production increased accordingly. This saving of a few seconds in time may mean all

the difference between producing the job as an economical pressed article or an uneconomical one, if very large quantities are involved.

There are several ways in which pressings may be made self-locating for asembly ; a small depression into which the mating piece will fit—a notch that will engage with an extension, or a half-sheared dowel fitting a hole ; all of these are fairly simple and common methods and in one form or another are capable of being incorporated in many fabricated products which are being designed to replace a complex sand casting. Some examples of articles which for many years have been produced as sand castings (mainly in cast iron) but which are now being produced as mild steel pressings are—electrical fittings, including decorative fittings and also junction boxes, elbows, switch boxes, etc., lavatory cisterns and even domestic slipper baths.

OTHER USES FOR SHEET METAL

What methods other than casting can be replaced by the use of sheet metal? One other at least comes to mind at once and that, of course, is forging, by the drop stamp, as distinct from hand forging, the latter, of course, being used mainly for the manufacture of articles of fairly large size that are needed in either one off numbers, or if more than one off, only in very small quantities for very special applications. Naturally in this case there is no question of even considering using sheet metal pressings, for tool costs alone would be too prohibitive and so rule out fabrication. For large quantity production, however, on suitable selected items, the possibility of using a pressing in place of a forging, will pay for investigation. This is particularly so should there be any considerable amount of breaking down work preparatory to the actual operation of forging. Likewise, as with castings, the elimination or avoidance of subsequent machining operations will enter largely into the considerations of production economics. There are cleaning and finishing operations to be performed with forgings just as there are

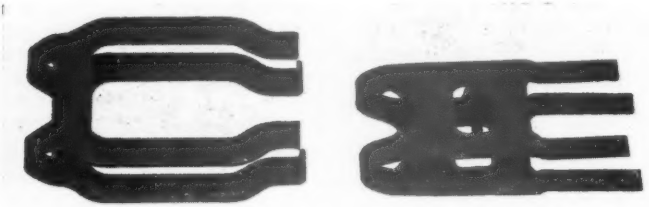


FIG. 3. A shackle for a weighing machine, produced as a pressing to replace the original forged product shown in Fig. 4.

with sand or die castings. The operation after the forging leaves the drop stamp is that of flash clipping, which is carried out under a power press built on very robust lines for this type of work.

A shackle made as a pressing to replace (or supersede) a forged one is shown in Fig. 3. Here again a brief comparison of the two methods may be of interest. The pressed component as shown is not quite complete, there being a further operation needed ; this operation being the piercing of holes in the legs, near to the bent-in ends, to receive retaining pins for a steeling which had to be fitted subsequently. The material used for this product was mild steel $\frac{5}{32}$ in. thick. The operation sequence to produce was as follows :—

Blank and pierce in combination tool

Bend

Bend end of leg

Pierce ends of legs

(This latter piercing was carried out as a separate operation in order to maintain accuracy and lineability.)

To make the product complete and ready for use it was carburised and hardened (penetration being about $\frac{1}{32}$ in.) and a hardened steeling, or knife edge, fitted at the open end. Therefore, we must add these additional operations for the purpose of our comparison :—

Cut off steeling from section rolled bar

Drill 2 holes (two-spindle drilling machine)

Mill knife edge

Harden (shackles and knife edge steelings were carburised and hardened in pans)

Grind knife edge

Polish " Vee " of shackle

Assemble

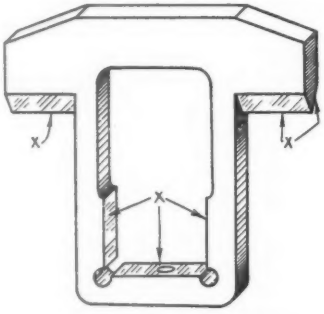
This, therefore, gives a total of 11 operations to complete a shackle assembly when fabricated from sheet steel. The result was a pleasing appearance combined with light weight and equal efficiency with the forged article.

The forged shackle which the pressing replaced is shown in Fig. 4. As the centre of this forging is open, it was necessary to prepare a blank ready for the drop forging operation. This preparatory work was carried out under the power press in two operations, which consisted of passing the strip of mild steel ($\frac{5}{8}$ in. thick by about 6 in. wide) through a pair of piercing tools to pierce out a rectangular hole slightly smaller in dimensions than the hole in the finished

forging, and then passing through a pair of blanking tools to blank out a shape roughly the same as the finished forging plus an allowance all round for sizing in the drop forging operation.

After the drop forging, the usual operation of flash trimming had to be carried out, after which the forging was passed to the machine shop for the machining operations. These consisted of drilling the two chip clearance holes in the bottom corners, broaching the inside, broaching the knife edges (two operations) and drilling the $\frac{5}{16}$ in. diameter hole in the bottom.

From the machine shop the product was passed to the heat treatment department to be carburised and hardened, after which it was returned to the machine shop where the knife edges were ground and the scale was removed from the inside broached faces.



FACES MARKED 'X' ARE BROACHED

FIG. 4.
The forged shackle which was replaced by the pressing in Fig. 3.

As with the pressed article, a steeling had to be fitted, but in this case it was a "Vee" steeling, in which a knife edge had to pivot, and was fitted in the internal broached surfaces. This steeling was made from section rolled bar as before and its production entailed operations almost identical with the previous one, the only difference being that there was only one drilled hole which had subsequently to be tapped before hardening.

We are in a position now to sum up the operations required to produce the shackle by the forged method. To take the forging first, we have :—

Pierce
Blank
Forge
Flash clip
Drill two chip clearance holes
Broach inside faces (one pass)
Broach one side of two knife edges
Broach other side of two knife edges
Drill one $\frac{5}{16}$ in. hole
Carburise and harden

Remove scale from inside faces (to ensure correct location)
Grind knife edges (one operation using swivel fixture)

To produce the steeling we have the following operations :—
Cut off from section rolled bar
Broach " Vee " seating for knife edge
Drill tapping hole
Tap $\frac{5}{16}$ in. Whit
Harden
Grind " Vee "
Assemble with forged shackle

Thus we have a total of 19 operations to produce a complete shackle assembly by this method, as compared with the 11 required to produce the substitute from sheet steel.

UPKEEP OF TOOLS

One important point to bear in mind in a case of this kind is the comparative cost of upkeep of tools by each method. Much higher production can be obtained from presses and press tools than from drop stamps and dies, and the quantities that can be produced between reconditioning bears but little relationship to the comparative time and cost of reconditioning the tools for the two methods. With press tools all that will probably be required is a regrind of cutting edges and a repolish of bend radii, but with drop stamping dies, the whole form will quite probably need to be resunk after only a few hundred forgings have been produced.

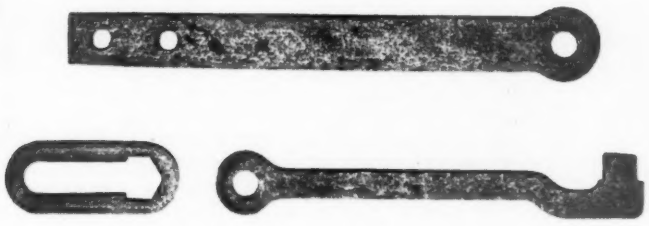


FIG. 5. Examples of parts produced as pressings to replace the more costly ones produced as forgings.

There are other examples of pressings which replaced forgings (Fig. 5) but a detailed comparison will not be entered into as the example just quoted will be sufficient to illustrate the comparative costs of the two methods. Similarly, the article shown in Fig. 6

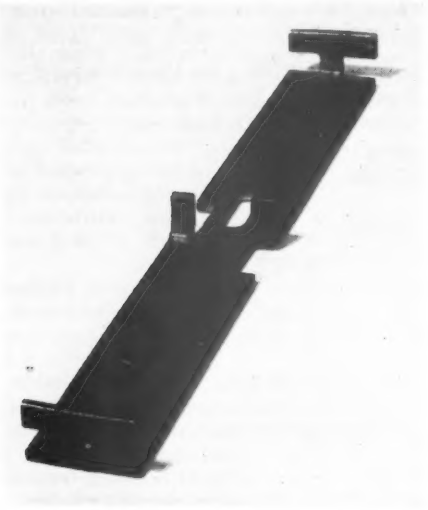


FIG. 6.

A rocker beam produced from strip mild steel in two press operations. This article replaced a similar one which was an iron casting with several subsequent machining operations.

will not be discussed in detail, but it is an interesting example of a pressing replacing a product which was previously produced as an iron casting with several subsequent accurate machining operations. As the article, as illustrated, was produced in two press operations only, the advantage of this method of production will be quickly realised, particularly if one remembers the comparative speeds and costs of press operations and casting, combined with such machining operations as milling or broaching.

One could continue almost indefinitely, quoting examples from actual experience where pressed articles from sheet metal have replaced articles produced by more expensive and slower methods.

SUBSTITUTION OF MATERIAL

It was stated at the commencement of this paper that one of the greatest single factors that has furthered the use of sheet metal in place of other materials, is probably the advent of the motor car. This itself affords us many examples of the substitution of materials, the most obvious of course being in the bodywork of the said motor car.

The early motor cars, as most of us remember, had the bodywork constructed of wood, and required many long hours of patient work on the part of skilful bodybuilders. When completed by the coachbuilder, the body in many instances was then passed over to the coach finishers for either painting or, very often, French polishing. The result was a most ornate affair which had but a limited life. Indeed it is very doubtful if timber bodies, as constructed in the early days, would be of very great use with modern speeds. Some timber bodies are being constructed at the present time, but mainly for shooting brakes or Utility vans, and even these are being gradually displaced by sheet metal bodies, in some cases painted and grained to represent timber.

Apart from the obvious problems of design that were present in the transition from the one material to the other, problems of contours, and those allied to them, to enable sheet metal to be formed into a suitable and acceptable shape, other difficulties also presented themselves. These problems were possibly unexpected to the early design engineers and were for a time a source of trouble and concern. Probably one of the most important which had to be overcome was that of "drumming" or resonance due to vibration being transmitted to the sheet steel bodywork. This particular trouble seems to have become more acute when sheet metal, for car bodies, ceased to be shaped by sheet metal workers and tinsmiths, and was drawn to shape in the large power presses now in common use for this class of work. This was probably due to the residual stresses left in the steel owing to its being strained beyond its elastic limit in order to obtain the required shape without elastic recovery.

Then again, the fact that there was substitution of sheet steel for timber led to other problems arising. As the technique of fabrication progressed from the old time hand sheet metal working to the present day highly developed press forming operations, it was found that the quality of material, required to withstand deformation, had to be improved as the techniques became more exacting. In consequence, the steel mill technicians had of necessity to improve their product. This, of course, has led to a vicious circle of events ; first the bodymaker evolves a technique which demands a better quality material, which the sheet metal roller then supplies. The press shop technician and tool designer immediately find that they can improve their methods and processes by use of the new quality material, until they again require an improvement in quality. The poor metallurgist again has to burn the proverbial midnight oil with a wet towel round his head until he has again satisfied the press shop demands, and so ad infinitum.

In this same field of substitution—sheet metal for timber—mention may also be made of refrigerator cabinets, where sheet steel is almost universally used at the present time.

WIDE VARIETY OF FINISHES

The introduction of sheet metal for such products as those already mentioned has been the means of opening up for the public a field of beauty in finish that was impossible with the original materials. With metal as the material of construction, it is possible to use a wide variety of industrial finishes ranging from vitreous enamel, down through the stove enamels to the cellulose finishes, each of these in its own sphere being available in a range of colours that is remarkable in its extent. Apart from the paint and enamel finishes there are, of course, the electro-deposited finishes which cannot be applied to the original non-metallic materials of construction. These finishes also have a very wide range and at the present day cover a field from the plain nickel and chrome plated finish on steel and non-ferrous metals to the anodised and dyed colour finishes on the aluminium alloy range of materials.

This latter range of alloys has also played its part in displacing other materials from constructional work where they were at one time pre-eminent. This is particularly so in architectural work, particularly where shop fitting and fashion salons are concerned. Whereas effects were once obtained by a skilful use and selection of different kinds of timber which were cut in such a manner as to expose the beauty of the grain, a single material is now used and finished as required. At times many species of timber were used to obtain the required effect and much expensive French polishing was needed in order to bring out and enhance the full beauty of the grains of each variety. Now, however, it is possible to depart from the solid looking and heavy type of construction associated with the use of timber as an architectural material. Lightness, strength and beauty are characteristics of the light alloys in building construction, and full use is made of these. The ability to bend, form, draw or otherwise fabricate the light alloy sheet into delicate shapes which can afterwards be anodised and dyed in a variety of colours, gives the imaginative architect an almost unlimited scope.

Not only the light alloys are being used for decorative architectural applications, however ; stainless steel sheet, strip and sections are taking their place in this class of work. So far, however, the progress made in substituting this particular material has fallen far short of the light alloys. This, no doubt, is due to several factors, weight, cost, short supply, the greater difficulty experienced in the working up of the metal, and the fact that only one finish is obtained satisfactorily, viz., a highly polished surface. This latter is perhaps one of the greatest obstacles in the way of wide utilisation of stainless steel for decorative work. Whereas the delicate and contrasting shades obtainable on the dyed light alloys can be very restful and pleasing to the eye, a great expanse of highly polished and glaring surface is very harsh and soon jars on one's nerves with its garishness.

Both of these sheet materials have, however, found a use in architecture apart from decorative uses, and have at the same time helped to solve a national problem and fill a national want. In this particular application the materials that have been replaced are neither timber or other metallic materials, they are brick and stoneware and the application is, of course, housing. The use of sheet metal for the building of pre-fabricated houses caused quite a furore when the project was first discussed, but prejudice has been broken down, with the result that metal houses are now an accepted fact. For the shell of the house, the most commonly used sheet metal is one of the range of light alloys. These light alloys have been chosen for a variety of reasons ; appearance, lightness, ease of fabrication and perhaps most important of all, their resistance to corrosion. Many of the interior fittings are also of light alloy, or light alloy in combination with stainless steel, the use in combination giving quite a good decorative effect. Stainless steel is used by itself for utilitarian purposes and for worksaving. One of the chief uses for stainless steel sheet in housing is the provision of domestic sinks, owing to the ease with which they can be kept clean and therefore more than ordinarily free from germs. Sink units, washing machines and cooker cabinets, where grease and dirt are likely to lodge, all find a use for this labour-saving material, to enable the parts to be easily and quickly cleaned.

SHEET METAL IN FURNITURE

We find on looking back that sheet metal has covered a fairly wide field in applications where substitutes were needed for other materials. As yet, however, this trend is still in its comparative infancy and it is felt that in the future still more and more applications will be found for the use of sheet metal. Office furniture, for instance, is already an accepted sphere in which metal is ousting the once universally used timber, but what of ordinary domestic furniture ? Some attempts have been made to introduce sheet metal into this field. So far, however, it appears to me that there are two drawbacks ; first, the usually offered furniture is too cold and uncomfortable looking, and in many cases amateurish looking in construction, and secondly, when a reasonably acceptable article is offered, the price is usually too prohibitive to attract the public.

This, however, does not mean that domestic furniture is an unsuitable field of application, far from it, for there is much scope for the designer and manufacturer to exercise their ingenuity.

Here is one instance only where sheet metal may yet displace the more orthodox material ; many others no doubt will occur to those people who are responsible for furthering this branch of industry, and it is visualised that new industries will spring up to exploit the possibilities that abound in the province of substitution of sheet metal for other materials.

AN ENGINEER'S SURVEY OF THE IMPACT EXTRUSION PROCESS

By RICHARD HANES, M.A. and E. G. GAMESON.

To be presented to the Wolverhampton Graduate Section of the Institution, on December 13th, 1949.

Extrusion may be defined as an operation in which a substance held in a container is forced through a small shaped orifice so as to take on the form of a rod, tube or other more complex section. Thus squeezing tooth-paste out of a tube may be looked upon as a simple everyday example of extrusion. A suitable set of tools for the extrusion of metals is shown diagrammatically in Fig. 1, and consists of a container, a ram which moves forward and applies the pressure to the metal slug, and a die in which the shaped orifice has been cut. The metal will extrude in the form of a rod, as indicated in the lower half of the illustration.

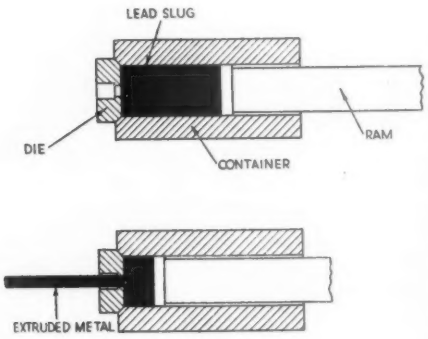


FIG. 1.

The main advantage of extrusion methods lies in the large reductions or changes in shape of the metal which can be effected in a single operation. If the rod were to be formed by drawing through the die, only a limited reduction in area could be achieved, as the whole of the drawing load would have to be taken by the rod. In contrast to this, no tensile stress is set up in the metal during extrusion, and the maximum amount of deformation is usually limited by the strength of the tools or other practical considerations of a similar nature.

Two variations of this simple tool design which have important application to impact extrusion are shown in Fig. 2. In both, a

tubular shape is formed, a pierced slug being used in the upper illustration. In impact extrusion practice, the upper diagram is known as direct extrusion (sometimes referred to as the Hooker process) and the lower as indirect extrusion. The tools are set up in a mechanical press, and articles in a variety of shapes, some of which are shown in Fig. 3, are turned out at the rate of about 60 a minute. To give some indication of the scale of the illustration, the tall solid-based tube on the right is 8 inches in length and 1½ inches in diameter.

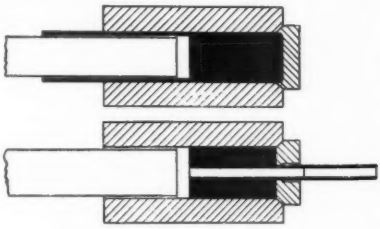


FIG. 2.

CHOICE OF METAL

Such enormous changes in shape of the slug take place during the operation that the metal requires to have a considerable capacity for plastic deformation. Metals which at room temperature have sufficient capacity include tin, lead, aluminium, copper, alpha brass, zinc and mild steel of good drawing quality, and as the slug is usually unheated, the choice of material must lie within this range. Although these metals have a large capacity for cold deformation, it does not follow that the pressures required to extrude them are low, and, in fact, one of the limiting factors for copper, brass, mild steel, and some aluminium alloys is the strength of the tools. Thus for the harder metals, the resistance to deformations, as well as the capacity for deformation, plays a part in determining whether or not the article can be successfully impact extruded.

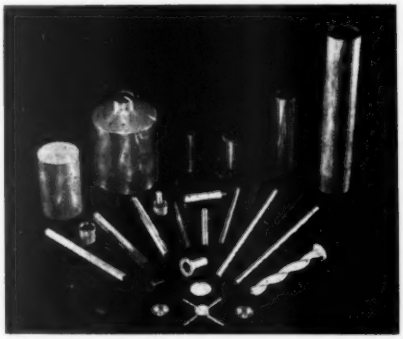


FIG. 3.

Collapsible tubes in tin and lead have been made by impact extrusion for over a century. These two metals are ideal material for impact extrusion, but are unsuitable for stiff containers of the sort usually made by deep drawing. A considerable advance in the art of impact extrusion was made at about the time of the first

world war when it was discovered that aluminium could also be impact extruded, and that after extrusion the metal was in a fully work-hardened state. Other metals, such as copper and brass, were also impacted successfully, but aluminium is by far the most popular metal, partly due to the fact that extrusion pressures are reasonable, and partly to the other advantages of the metal, such as resistance to corrosion and low price. Well known examples of impact extrusion of aluminium are condenser cans and valve shields in radio.

INDIRECT EXTRUSION

It is proposed first to study in greater detail indirect extrusion, that is to say, the formation of hollow tubular articles having a solid base. A diagram of suitable tools is shown in Fig. 4. These tools are set up in a power press with the punch rigidly held, and the cross-head well guided. The extruded product sticks on the punch and is stripped off by means of the stripper plate, on the upward stroke of the press. An example of an actual set up in a horizontal press is shown in Fig. 5. The punch, die and stripper can be seen clearly. Slugs are fed from a hopper above the picture, fall down a chute, are placed in the die by a finger operated by cam action. After the extrusion, the products fall on to a moving belt which carries them away. In a vertical press, the products are often blown away by a sudden blast of air.

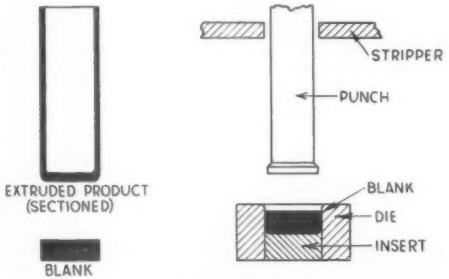


FIG. 4.

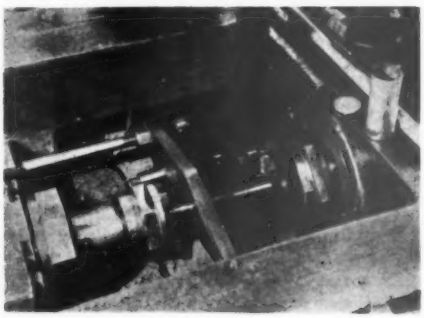


FIG. 5.

Such a press is run at about 60 r.p.m., and at this speed it can well be imagined that the punch strikes the blank with a sharp blow. It is from this feature that the name " impact extrusion " is derived, although it

is not at all certain how important the speed of impact is to the successful carrying out of the operation. After extrusion the products are too hot to handle, but are not at a high enough temperature to cause annealing of the material.

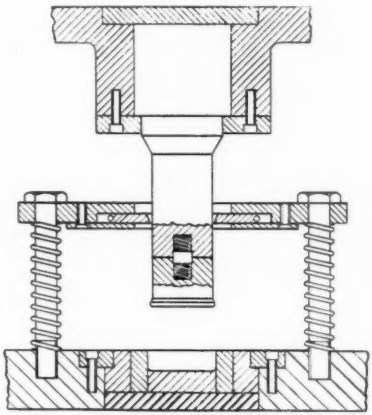


FIG. 6.

A detail drawing of a set of tools intended for a vertical press is shown in Fig. 6, in which certain points of interest can be seen :—

1. The shallow die, with radius in the bottom corner. The base is made separate from the walls, and the two parts force fitted together. The die is also force fitted into an outer ring. Such a design is needed because of the very high bursting pressures encountered.
2. The punch is very firmly encastered in the cross-head, so that any tendency to wander is minimised. For this reason also, the press itself must be sturdy and well guided.
3. The stem of the punch is smaller in diameter by a few thousandths of an inch than the face, and the length of this larger portion is about $\frac{1}{32}$ inch. This enables the punch to give maximum guidance to the product while keeping the frictional force to a minimum.
4. The working end of the punch is a separate piece screwed on to the stem. As this portion is the only part which wears out, the stem and base of the punch do not need replacement using this design.

A screw-top container for medicinal tables, in aluminium, which has been made in quantity by impact extrusion is shown in Fig. 7. On the left is the product after extrusion and trimming, and on the right the finished article, thread rolled and anodised. The size is $1\frac{1}{4}$ in. by $2\frac{1}{2}$ in., with a wall thickness of 0.014 in.

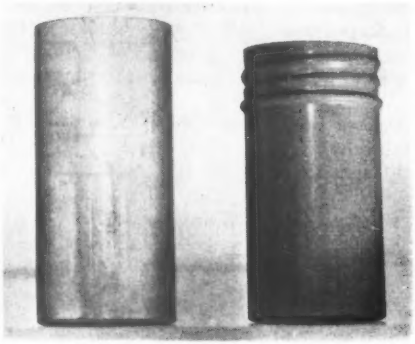


Fig. 7.

In making containers of this type, various faults are met with, three of the most common being shown in Fig. 8. The product on the left shows deep score marks on the lower part of the wall. These may be due to the use of too little lubricant, or faulty design of tools, and may be very difficult to eliminate. In the centre product, the roughened, pitted surface results from too liberal a use of lubricant, while the right hand product has a split in the wall, due to misalignment of the tools, a fault usually occurring only in thin walled tubes.

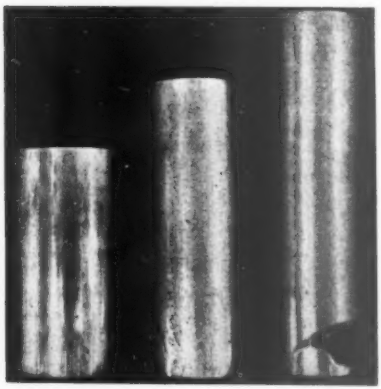


Fig. 8.

Fig. 9.

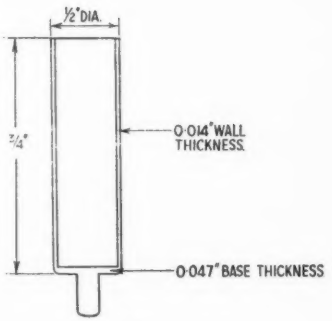


FIG. 10.

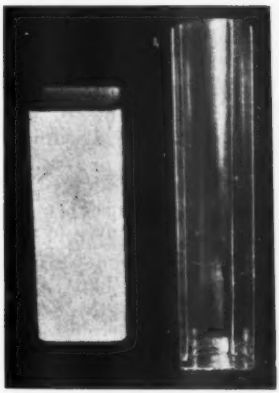


FIG. 11.

IMPORTANCE OF LUBRICATION

The question of lubrication is clearly an important one. For aluminium, the slugs are barrelled together with a quantity of lanolin dissolved in some solvent such as white spirits. They must be barrelled until they have a matt surface all over, and the solvent must then be completely evaporated. This matt surface is important, for highly polished slugs will score the tools immediately. On the other hand, bad marks in the slugs will appear on the finished product, par-

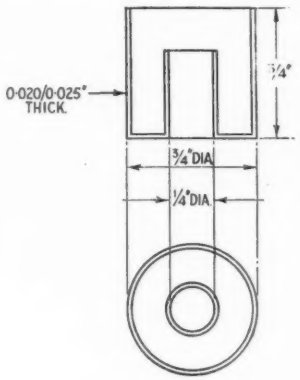


FIG. 12.

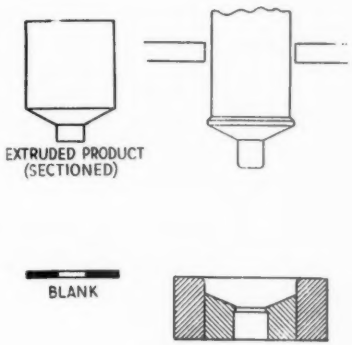


FIG. 13.

ticularly a ragged corner on the bottom of the slug which will cause a line part of the way up the product on the outside.

To illustrate the important limitation that the amount of deformation taking place under impact extrusion must be within the capacity of the metal, a product has been extruded from a magnesium slug, magnesium being a metal with a very small capacity for deformation at room temperature. The illustration in Fig. 9 requires little comment. It is important to note that the load required in this instance was not excessive, not as much, for instance, as would be required to make a successful product in copper.

Many variations in design from the simple shape so far considered are possible. Articles with thick bases and thin walls are as easy to make as those with thin bases, a quite different situation from that obtaining in deep drawing. The base can also be shaped, as shown in Fig. 10. This product may tend to stick in the die and a bottom ejector should be provided.

Fig. 11 shows two other variations in shape which are difficult to produce by deep drawing, but comparatively easy by impact extrusion methods. The first is a square can, with rounded corners, and the second a sectioned view of a can with longitudinal ribs in the walls. The metal may also be made to flow in two directions at the same time as shown in Figs. 12 and 13.

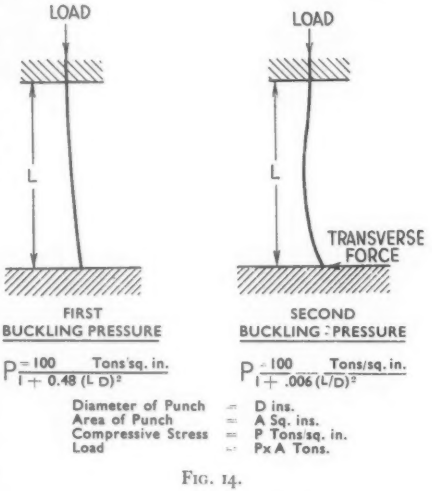


FIG. 14.

REASONS FOR TOOL FAILURE

One way in which the tools may fail when overloaded has already been mentioned, namely, bursting of the die. Another way, and one which can have more serious consequences, is the shattering of the punch due to buckling. This applies more particularly to slender punches, where the tendency to buckle under axial loading is greater. If the punch be considered as firmly encastered in the cross-head of

the press, and only the stem of the punch can buckle, then the well-known formulæ for buckling of struts can be used (Fig. 14).

Two modes of buckling are conceivable, one in which the face is free to move laterally, and one in which it is restrained, and for each of these, a theoretical buckling load can be calculated. The actual maximum permissible load will be somewhere in between the two values. When the first buckling pressure is exceeded, there will be an increasing tendency for the punch face to wander and make eccentric products, but the punch will not shatter until the second buckling pressure is approached.

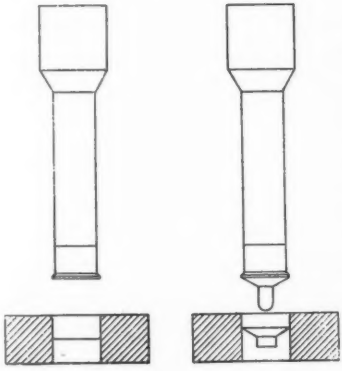
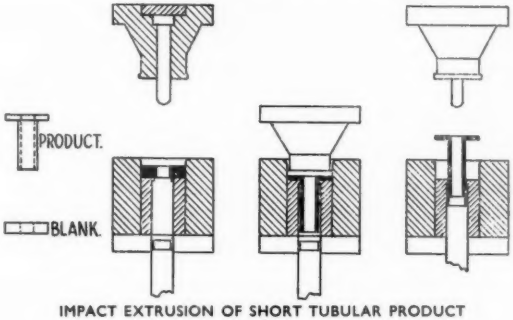


FIG. 15.

Clearly, if any means can be employed which tends to prevent the punch wandering, then higher loads can be employed and greater reductions effected. Punch noses with domes or roughened surfaces are frequently used. For some articles, the actual shape of the tools gives some advantage, as in Fig. 15, which shows on the right a set of tools for impacting collapsible



IMPACT EXTRUSION OF SHORT TUBULAR PRODUCT

FIG. 16.

tubes. The tube nozzle is formed by a spigot on the punch and a recess in the die, the back hole of which is a sliding fit on the spigot, and therefore acts as a guide to the punch. In such tools the tendency of the punch to wander is reduced to a minimum.

DIRECT EXTRUSION

In direct extrusion, shown diagramatically in Fig. 16, the question of buckling does not arise, as very sturdy tools can be used. As a result, much higher reductions and harder materials can be impact extruded. Certain features of the tools may be noted :—

1. The die is again made in two pieces, force-fitted together.
2. The back hole of the die is opened out a few thousandths of an inch, in much the same way and for the same reason that the indirect extrusion punch stem was reduced in diameter.
3. The punch is made in two parts, the larger part fitting closely into the die to minimise back extrusion.

In this example the product is extracted back through the die, by means of a bottom extraction mechanism. Products to this design have been successfully made from an alloy of copper and zinc containing 85 per cent. copper, the slug being a little over half an inch diameter.

Further interesting features of this type of extrusion are revealed in Fig. 17. A forming operation is carried out on the slug before extrusion, and a closed ended product is produced with tapered wall thickness. Great care has to be taken in matching the slug forming and extrusion tools—if the punch nose is too long, the base is blanked out of the product, while on the other hand, too short a punch nose gives a distorted shape to the wall adjacent to the base. The fourth operation in the illustration is merely a sizing operation.

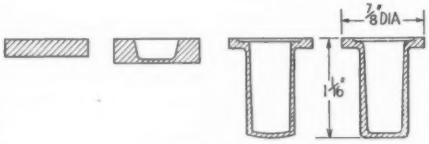


FIG. 17.

If the extruded tube is too long to be conveniently extracted back through the die, and if the flange is not required on the end of the tube, a procedure is available involving clipping the tube from the disc, as shown in Fig. 18. The press is provided with two punches, fixed to a sliding mechanism which brings each punch in turn above the die, as shown in the illustration. The second punch clips the disc from the tube and withdraws it from the die on the upstroke. The disc is removed from the punch on its idle stroke,

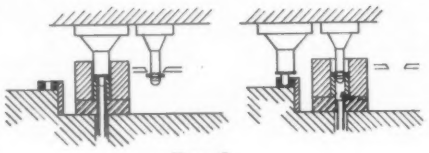


FIG. 18.

by an extractor, while the idle stroke of the extrusion punch is utilised for picking up a new slug to be carried into the die on the punch spigot.

Tubing can be made in considerable lengths and with a variety of cross-sections, a few of which are shown in Fig. 19. In these examples, the wall thickness is about 0.010 in., the diameter or side measurement about $\frac{1}{4}$ in. and the material aluminium. The product second from the top can be seen to have spiral ribs running along the outside of the tube. A further example of spiral ribbed tubing is given in Fig. 20. No supplementary mechanism is required to produce such articles, the spiral resulting merely from cutting the die flutes at the correct angle. Naturally, only comparatively open spirals can be made this way, and the technique would not be applicable to making screw threads.

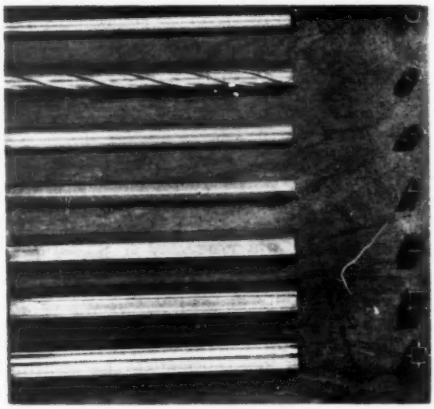


FIG. 19.

FIG. 20.

FACTORS AFFECTING METAL FLOW

The flow of metal during impact extrusion can be illustrated by a simple and effective technique, that of sectioning, polishing and etching the article. Fig. 21 shows the result of such treatment. The extrusion slug was cut from hot extruded rod, and the directional texture of the rod can be seen in the undeformed metal. In the extruded portion, the lines are too crowded together to give any useful information, but the flow of metal immediately before the die is well defined.

It is important when extruding any but the shortest tubes that a radius be formed in the bottom corner of the die, to help the

metal flow. The use of a square die with no radius results in the formation of a ring of metal in the corner which is detached from the disc and is left behind when the die is removed. The metal in the following slug flows over the surface of this ring, and bad scoring takes place, with small pieces of the ring becoming embedded in the extruded tube. This ring can be seen in Fig. 22, which shows the discard sawn from the end of a ribbed tube, with the ring partly attached.

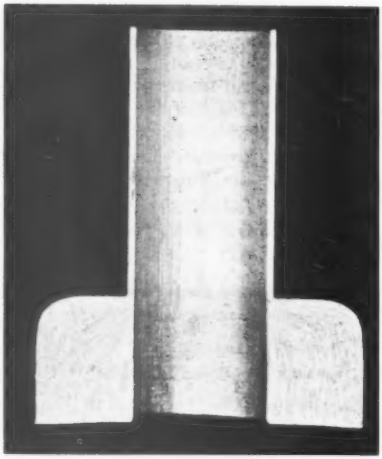


FIG. 21.

The formation of a ring of metal which has failed to flow with the rest of the metal provides a simple illustration of an important point, namely, that a continuous streamlined flow of metal must be insured throughout the operation. Complex shapes can be extruded provided this condition holds, whereas even the simplest designs will fail to extrude correctly if an area of "dead" metal is formed.

An attempt has been made to extrude a coated slug to form a tube with a coating on the outside face, the sectioning and etching method being used to investigate the consistency of the coating. Fig. 23 shows the cross-section as impact extrusion is commencing. The slug was made by blanking from strip, as can be seen by the drawing up of the coating at the outside diameter, and the central hole was drilled. The results obtained from an eight-inch length of tube, with a diameter of about $\frac{1}{4}$ in., by sectioning, etching and measuring with a travelling microscope, are shown diagrammatically in Fig. 24. As can be seen, the coating, although somewhat variable, is in this example continuous.

FIG. 22.

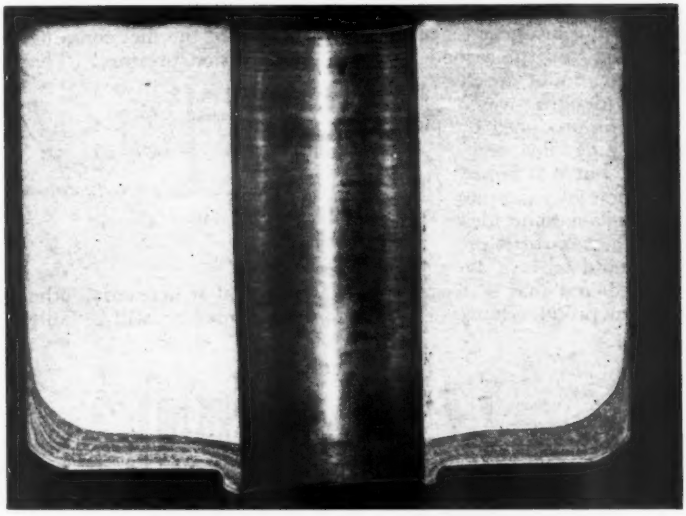


FIG. 23.

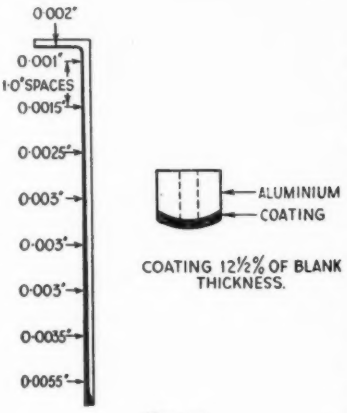


FIG. 24.

A further example of the extrusion of coated metal is given in Fig. 25, the product being made from 20 gauge tinplate. On the right is seen an enlarged view of one of the domes shown on the left, the wall thickness being about 0.006 in., and the diameter 0.176 in. The article is an interesting variation of the indirect extrusion technique, using a very shallow die so that the extrusion slug does not become detached from the remainder of the strip. The disc containing the three domes is blanked out at a later stage in the manufacture.

An even more unusual variation of impact extrusion technique is shown in Fig. 26, where split dies are used, and the metal is extruded sideways to form a product somewhat resembling the

hub and spokes of a wheel. A double-action press is required, the first action bringing together the two halves of the die, containing the slug, and the second applying the extrusion pressure. There are no doubt many other designs which could be produced by developing this technique, but it is hoped that these few examples have given some idea of the possibilities. It should always be remembered that a streamlined flow of metal is necessary, otherwise the product, however correct to shape it may be, will be faulty.

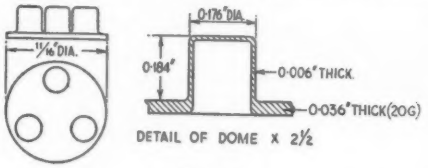


FIG. 25.

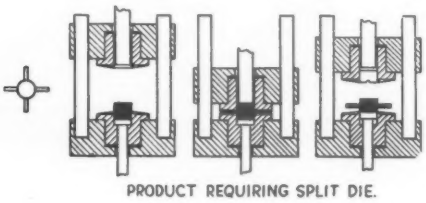


FIG. 26.

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Notes

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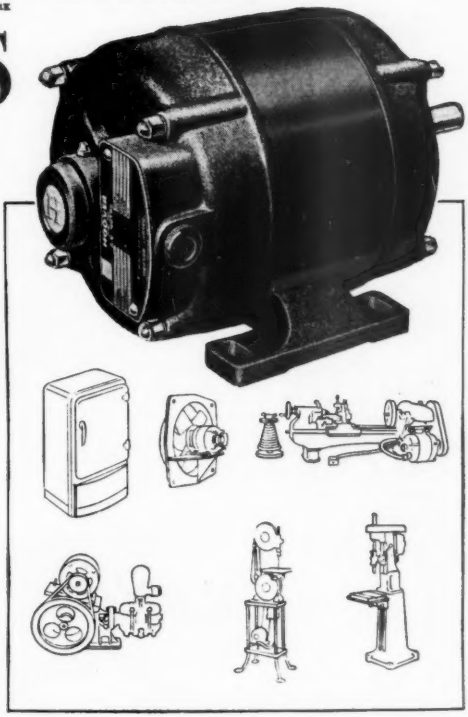

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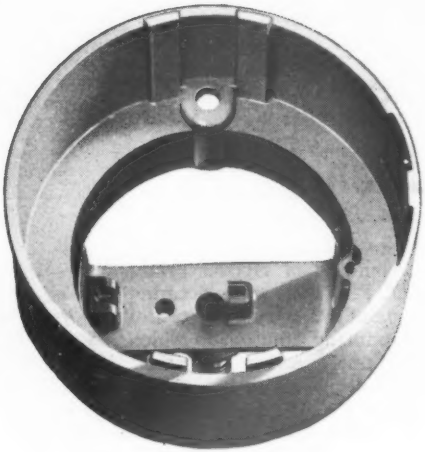

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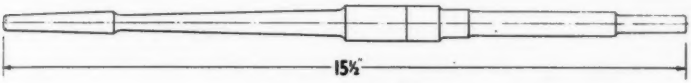

CINCINNATI FILMATIC No. 3 Centreless Grinder, increased in width to accommodate the three-segment grinding wheel in the foreground. A ground part appears in the front of the wheel, and a drawing of the part is shown above.

SEVEN DIAMETERS ON SLENDER 15½" SHAFT

ground in one operation

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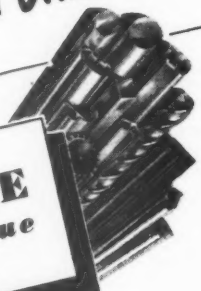

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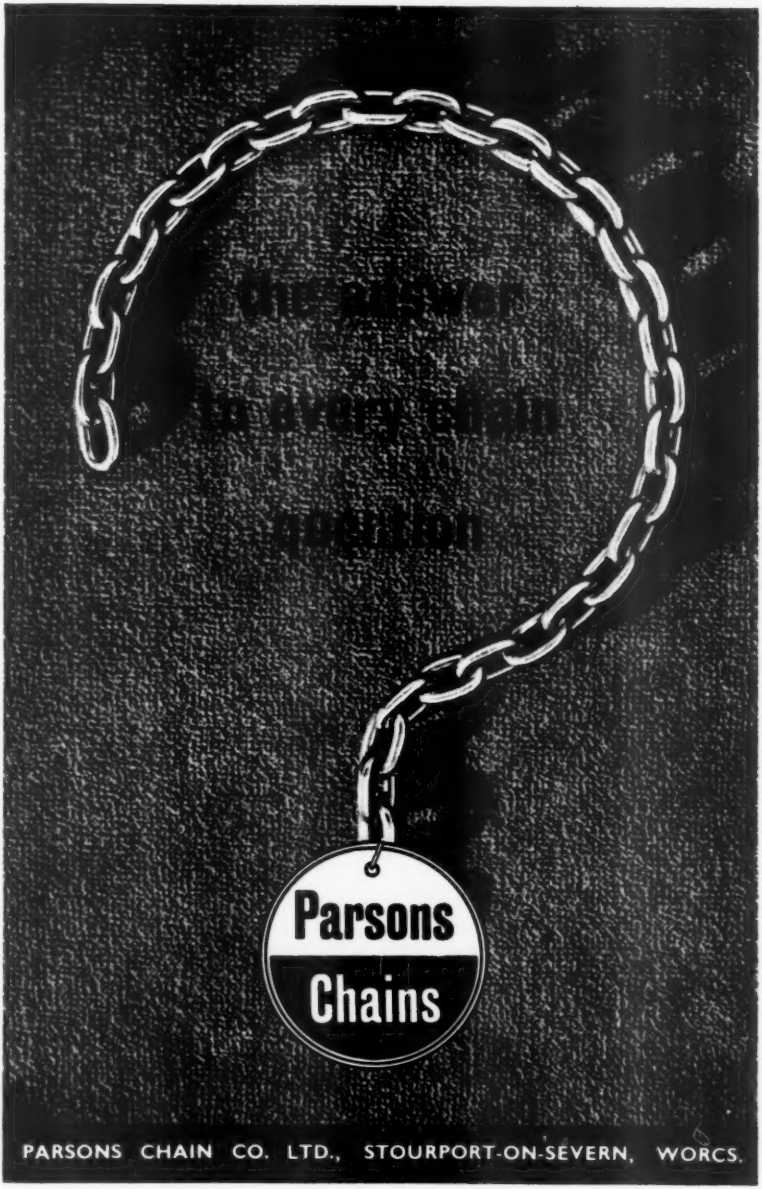
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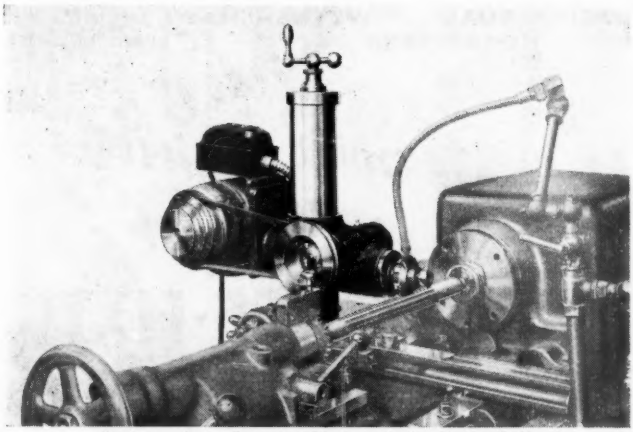

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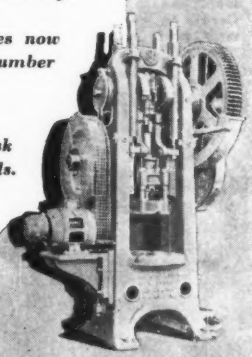

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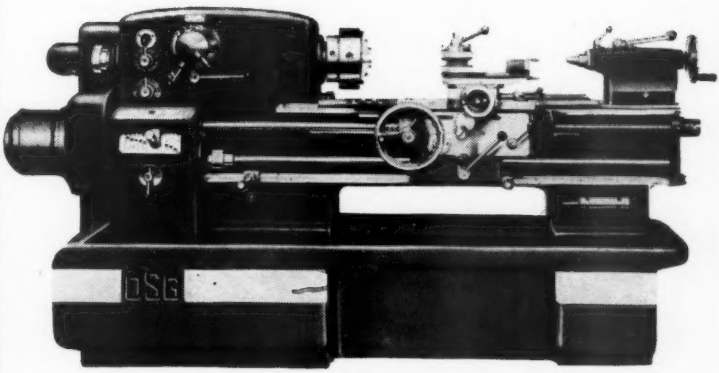

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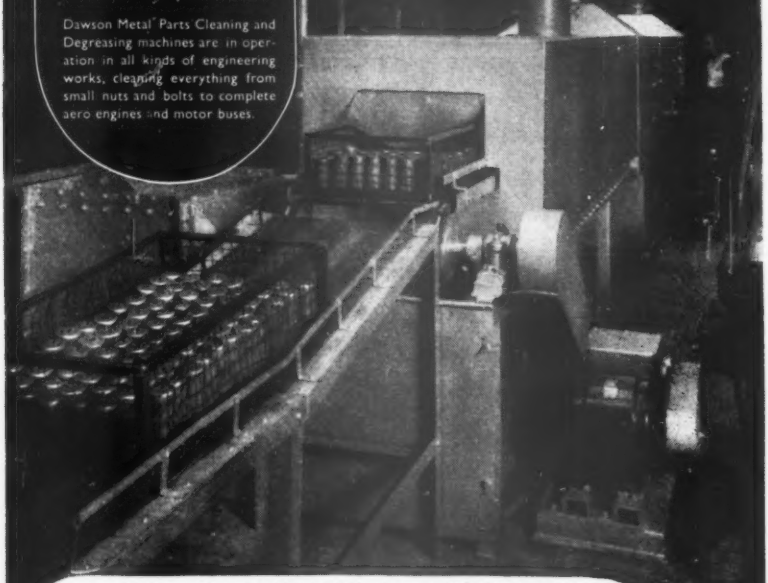

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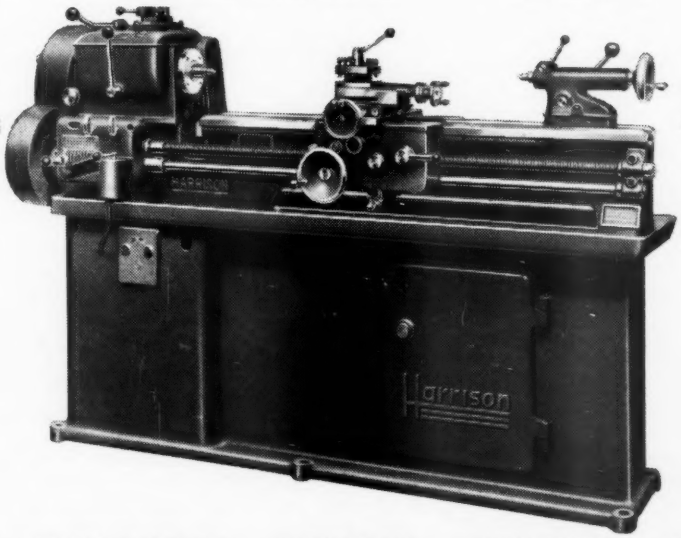

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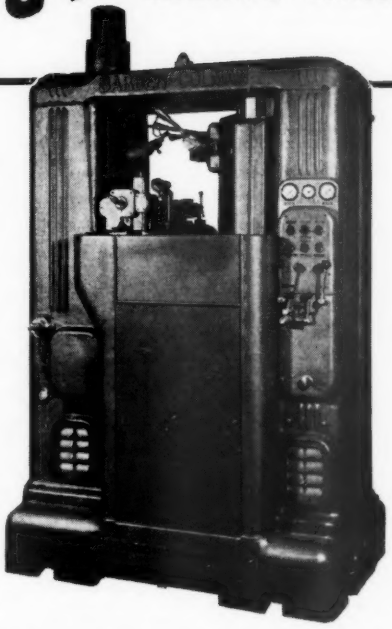

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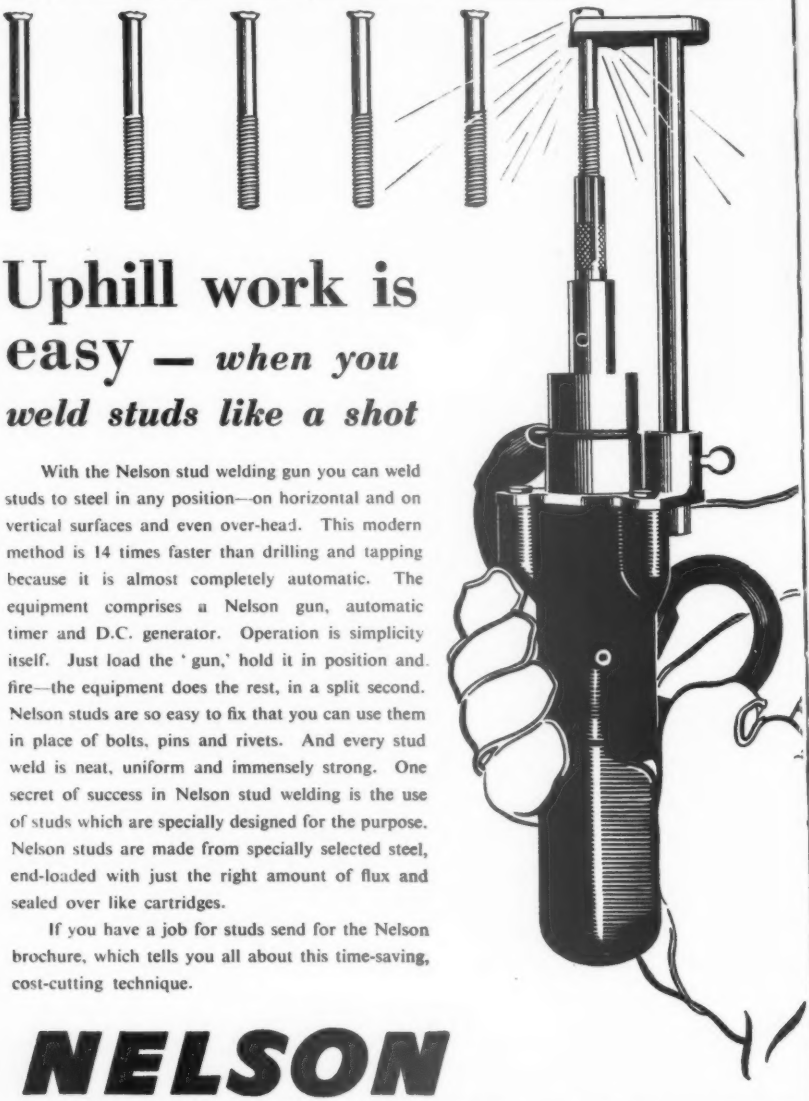

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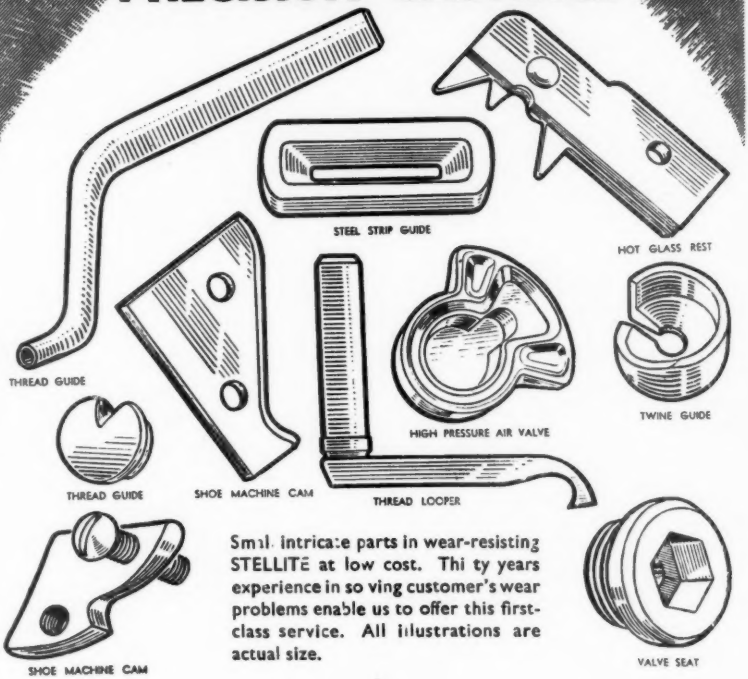

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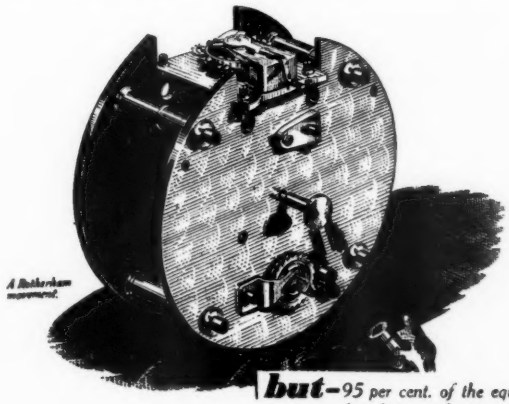

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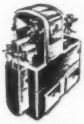
Some of the machines in the range are shown here.



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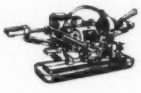

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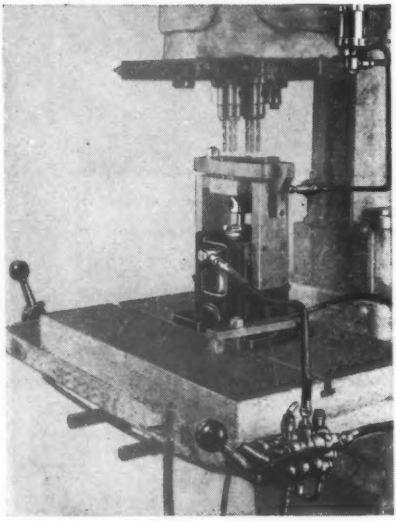

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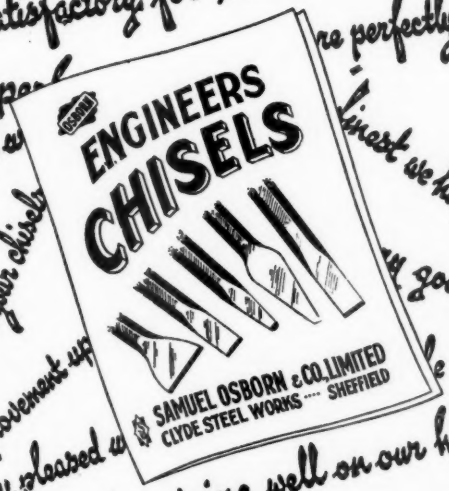

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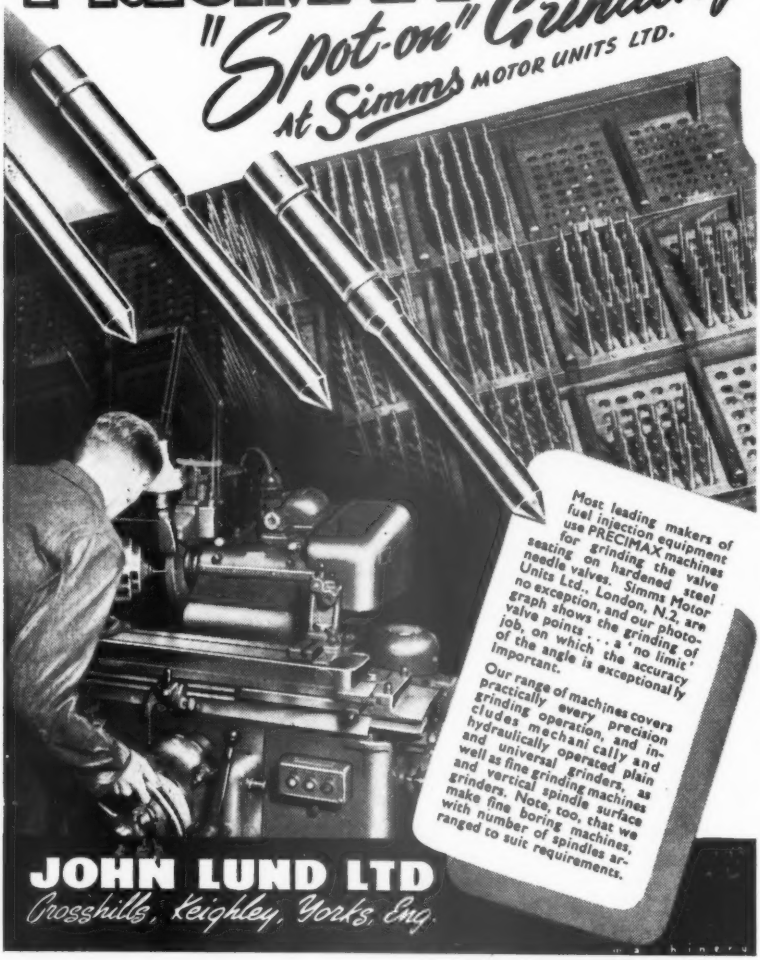

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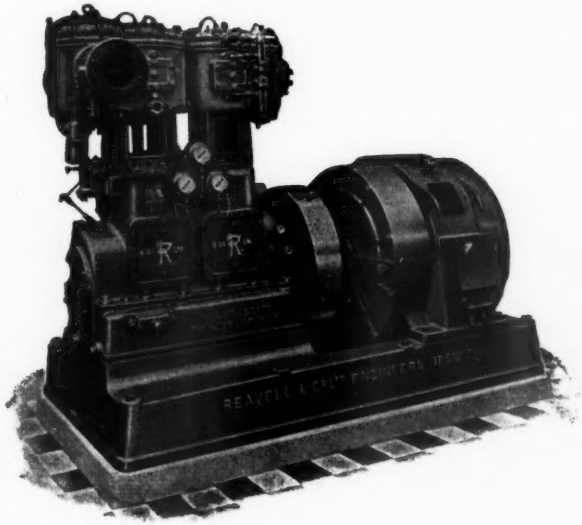

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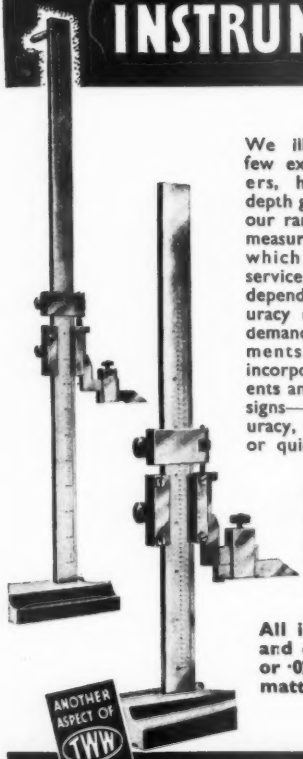

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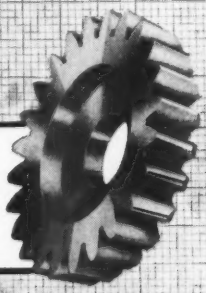

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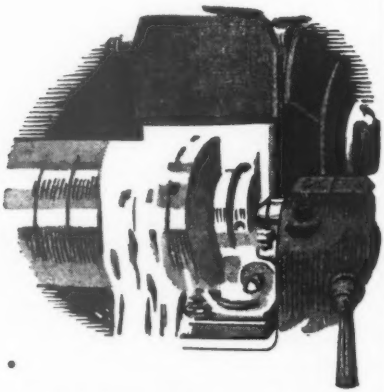

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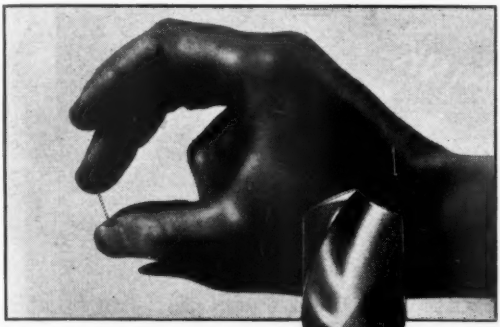

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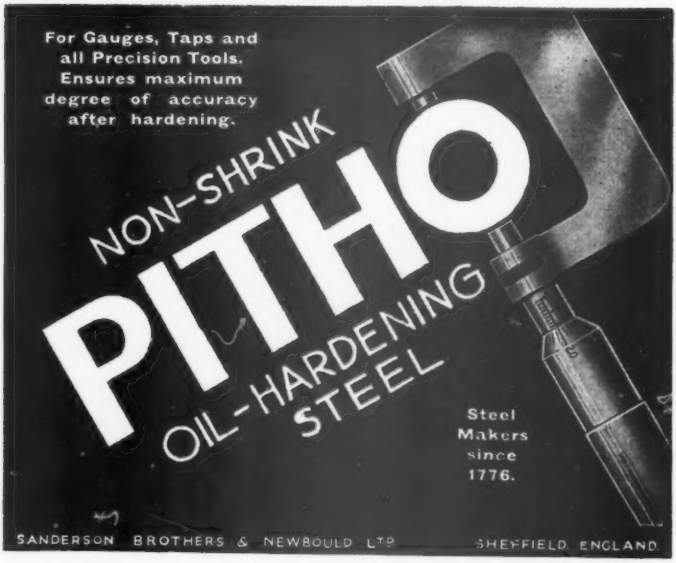
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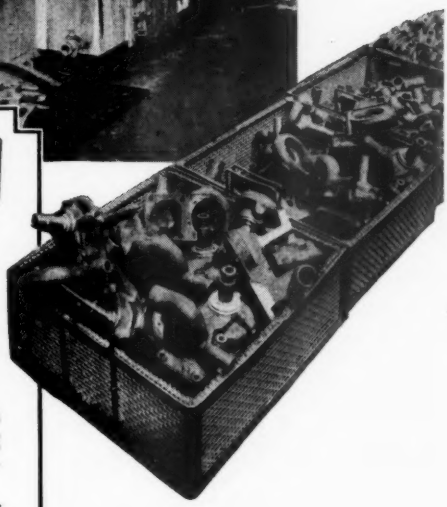

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This illustration shows a machine cleaning crank cases in the production line.

It is equally capable of cleaning small parts in baskets.

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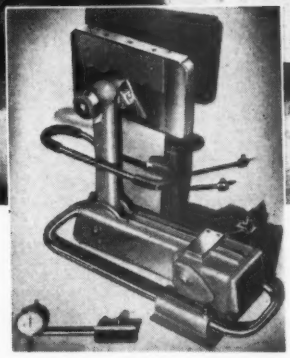

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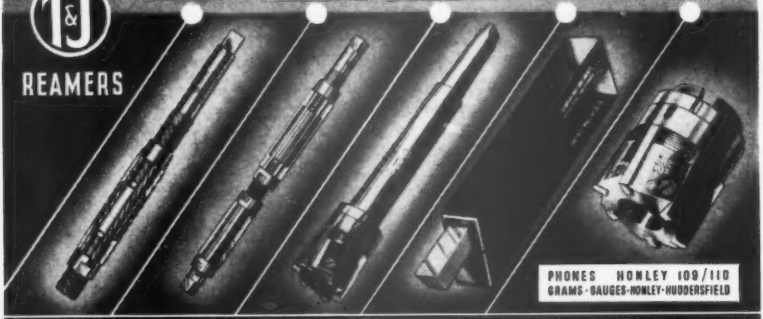

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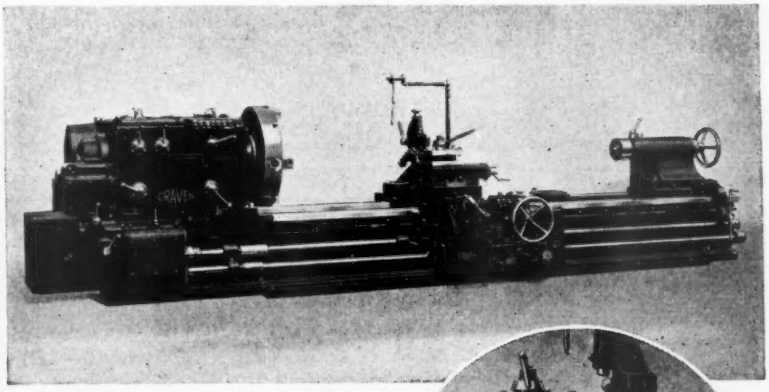

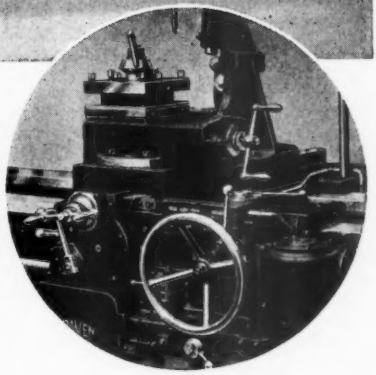

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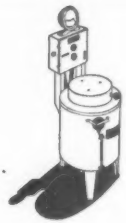

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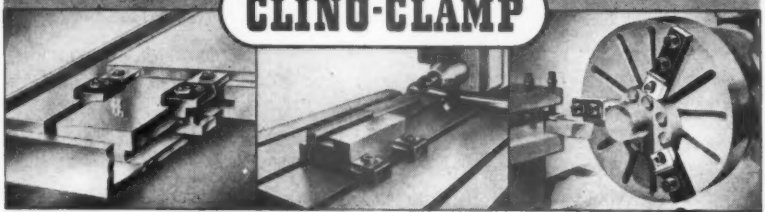

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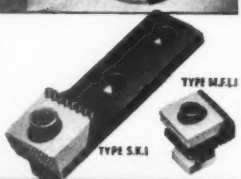

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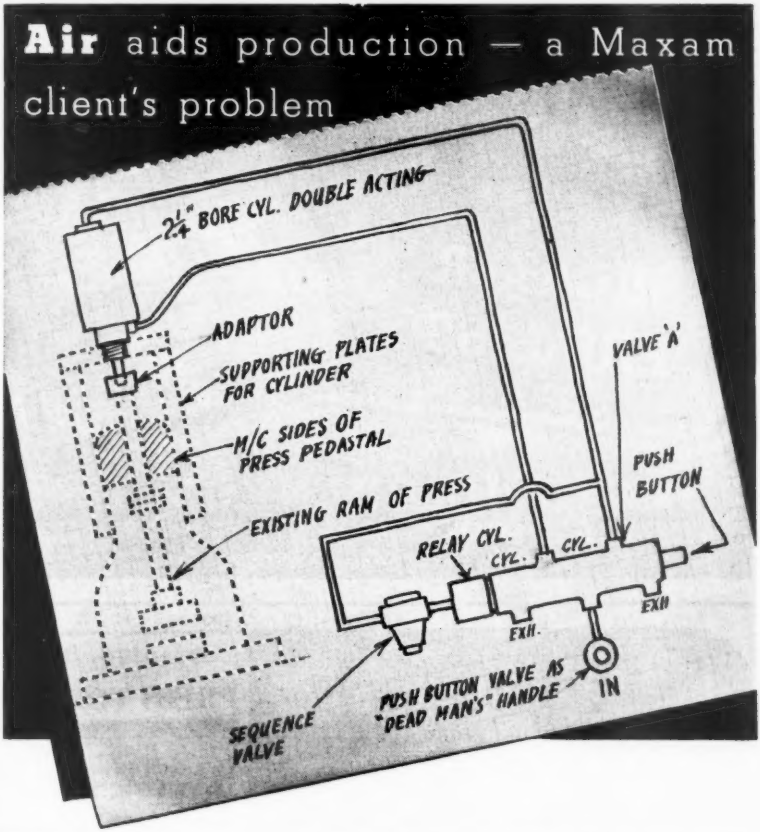

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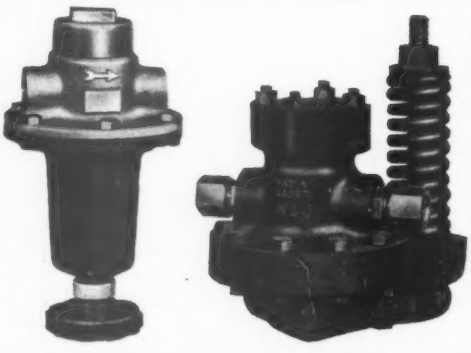

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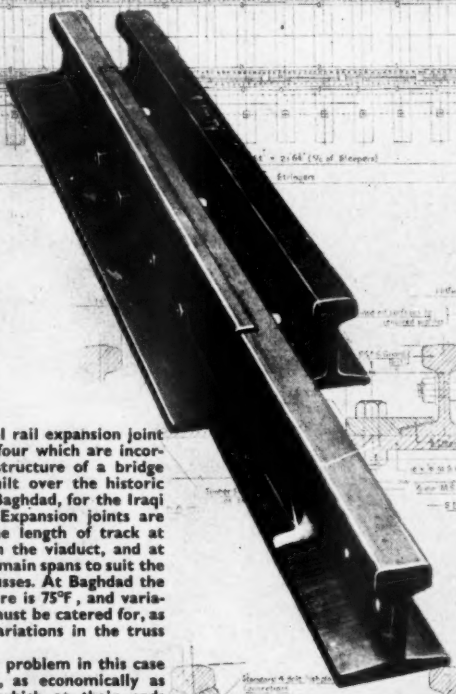

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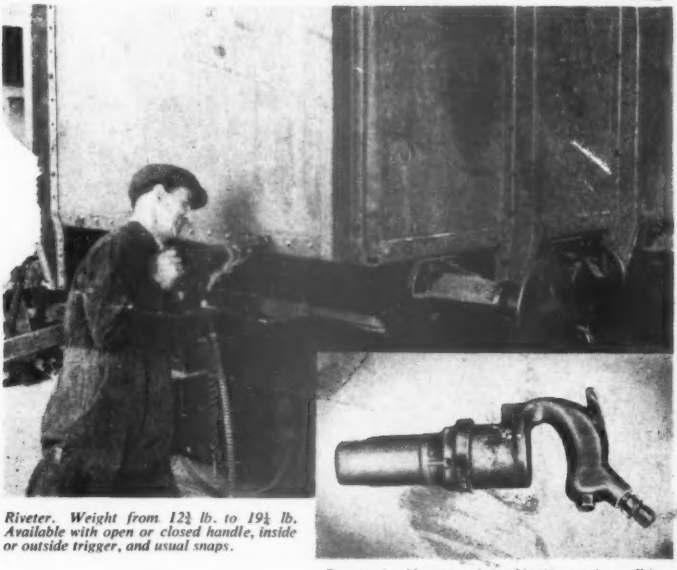

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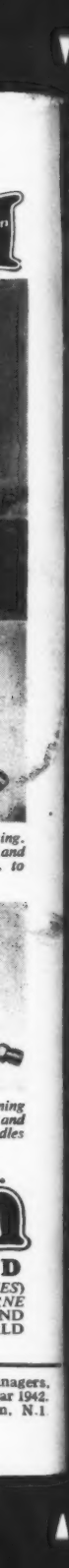
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